MASTER

Fast field fedback

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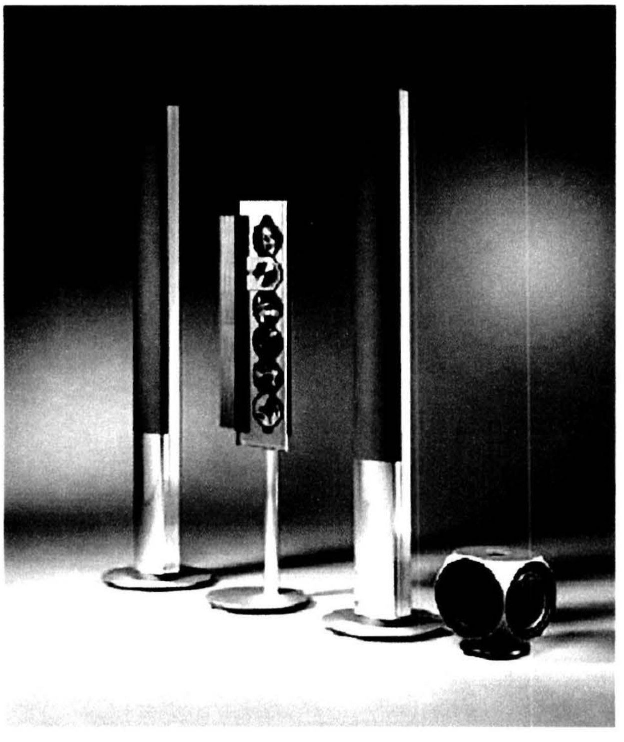
Award date:
2002

Eindhoven University of Technology
Faculty of Technology Management
Section Quality of Products and Processes

Bang & Olufsen A/S
Corporate After Sales Service
Struer, Denmark

Fast Field Feedback

A fast feedback structure of customers' product quality & reliability experiences that facilitates performing a Root Cause Analysis. Communicating this information to the main Product Creation Process for making improvements to product and/or process of a high-end consumer electronics company.



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December 2001

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Abstract

The thesis project Fast Field Feedback resulted from the research program of Bang & Olufsen and the Eindhoven University of Technology. The research program describes the roadmap for Bang & Olufsen to improve the information flow of collecting and analysing the field information. The method used is the Maturity Index on Reliability; it reflects the capability of an organisation to manage quality and reliability. The present state of Bang & Olufsen is MIR level 2, meaning that the business process is able to determine the location of failures. The ultimate goal of the research program, however, is to reach MIR level 4, which means continuous improvement and includes preventing quality and reliability risks in future products.

Management summary

The management summary describes each chapter from the report shortly to provide a general understanding of the graduation project.

1. Introduction

An aspect of improving the quality and reliability of products and processes is to improve the use of information from the market. The market information is quality and reliability related information about the behaviour of the products in the market. To fully utilise this information it needs to be available fast and in a suitable form for a root cause analysis. This resulted in the project with the following objective, expected results, deliverables and scope.

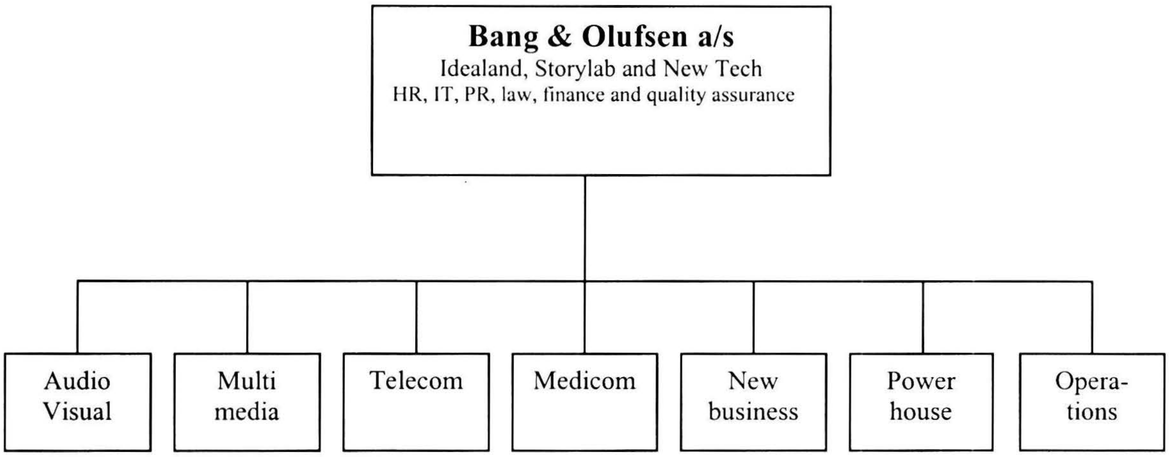
<u>Objective</u>
The objective of the project is to develop an approach to improve and implement a rapid feedback structure on product and process quality and reliability failures. A well-established and formal program organisation has to be developed to allocate and identify the root causes of quality & reliability issues at both business and technical process level.
<u>Result</u>
The result of the project will be:
- A flow diagram for Fast Field Feedback.
- A description of activities required for defining, implementing, and executing the feedback structure, focusing on root cause analysis.

<u>Deliverables</u>
The deliverables of the project will be the case description with a presentation and implementation of the Fast Field Feedback Structure.
<u>Project scope</u>
The scope and boundaries of the thesis project are limited to:
- An audio/video product, including the interfaces with its customers. The development and manufacturing of telephone and medical products have other characteristics than the audio/video products, although the distribution of telephones is mostly through the same channels as those of the audio/video products.
- The topic of fast field feedback covers the gathering and processing of field information about products at Bang & Olufsen. The project will strongly focus on the gathering and processing of field information, and especially the time and root cause aspects are considered. The internal actions that are undertaken in relation to the field information are given less attention.

The results and deliverables of the Fast Field Feedback structure are translated in a number of improvement goals:
- Decrease in the number of No Fault Found (NFF)
- Reaching Maturity Index on Reliability level 3, opportunity for MIR 4
- Improvements to running products and/or production process
- Learning from previous product quality & reliability problems
- Predicting future field behaviour
- Anticipating future product quality & reliability risks

2. Bang & Olufsen in general

Bang & Olufsen develops, manufactures and sells high-end video, audio and telecom products for the consumer market, furthermore it manufactures products for the medical market. Recently it has also expanded into new areas, such as car stereo and multimedia products. The products, which Bang & Olufsen puts on the market, are particularly well known for the design.



Bang & Olufsen organisation structure

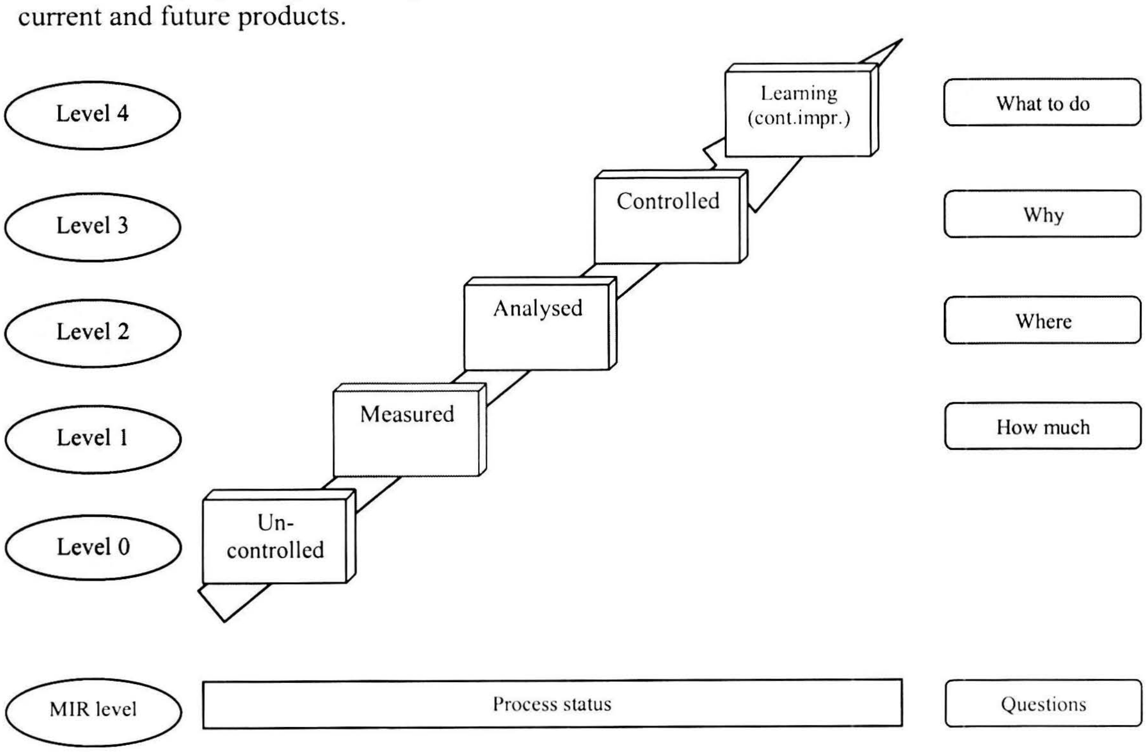
3. Literature

This project has a wide scope and a multitude of literature has been described, however, the Maturity Index on Reliability has a central place in the project.

The MIR assessment is a tool used to measure and improve the quality of the reliability-related information in the control loop (technical aspect) and the deployment of this information into the business processes (organisational).

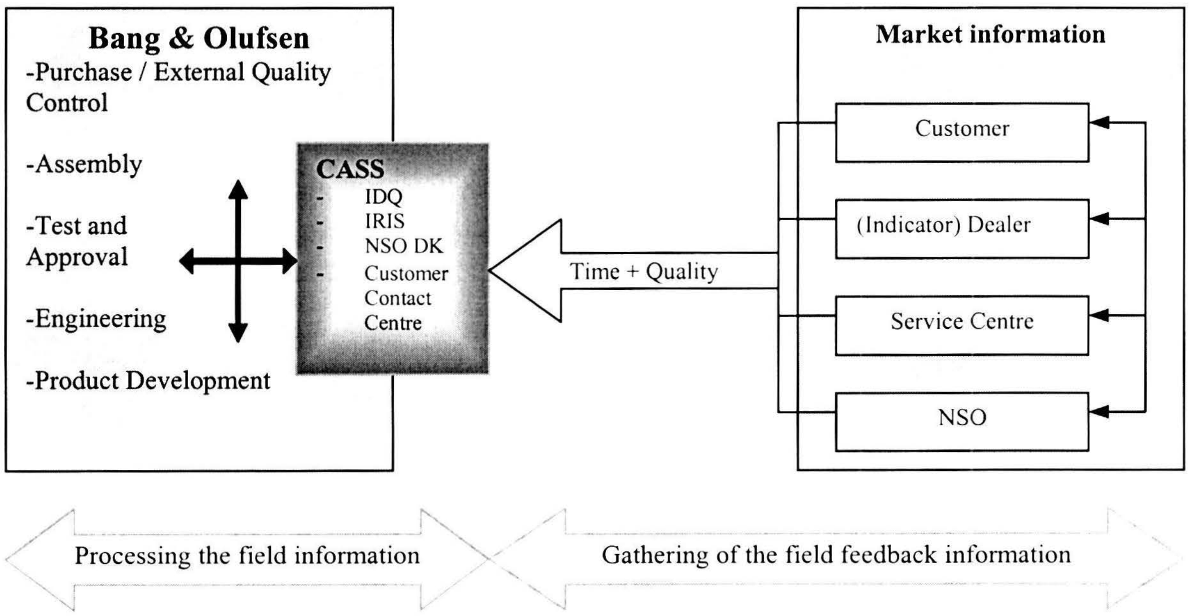
Analysing the reliability or safety of a product will require not only the analysis of the technical aspects of a product, but also the analysis of the (quality of the) reliability control loop of the organisations developing and operating a product. The quality of the reliability control loop can be measured in two aspects:
- The quality of the reliability related information in this loop; and
- The deployment of this information into the business processes.

In order to measure these aspects, the MIR concept is used. This scale of four levels reflects the increasing capability of an organisation to analyse, predict and improve the reliability of current and future products.



4. Field feedback within Bang & Olufsen

Corporate After Sales Service (CASS) is the closest contact in Bang & Olufsen to the market with regard to after sales service information (see figure), and the most suitable for getting product related failure information from the field. The focus will be on gathering the product related failure information and especially the time and quality aspects of the field information. In time means fast enough to start the Product Improvement Process for changes to running products and improvements in next generations. The quality of the information means whether the field feedback facilitates a root causes analysis.
If the behaviour of products in interaction with the customer is well-analysed and communicated, recurrence of old problems in new products can be avoided. However, with respect to Fast Field Feedback attention will only be given to processing the information when it is relevant for a root causes analysis. That the analysed root cause information is communicated throughout the organisation to make changes to running- and next generation products is part of the project scope, however, not how these activities are performed.

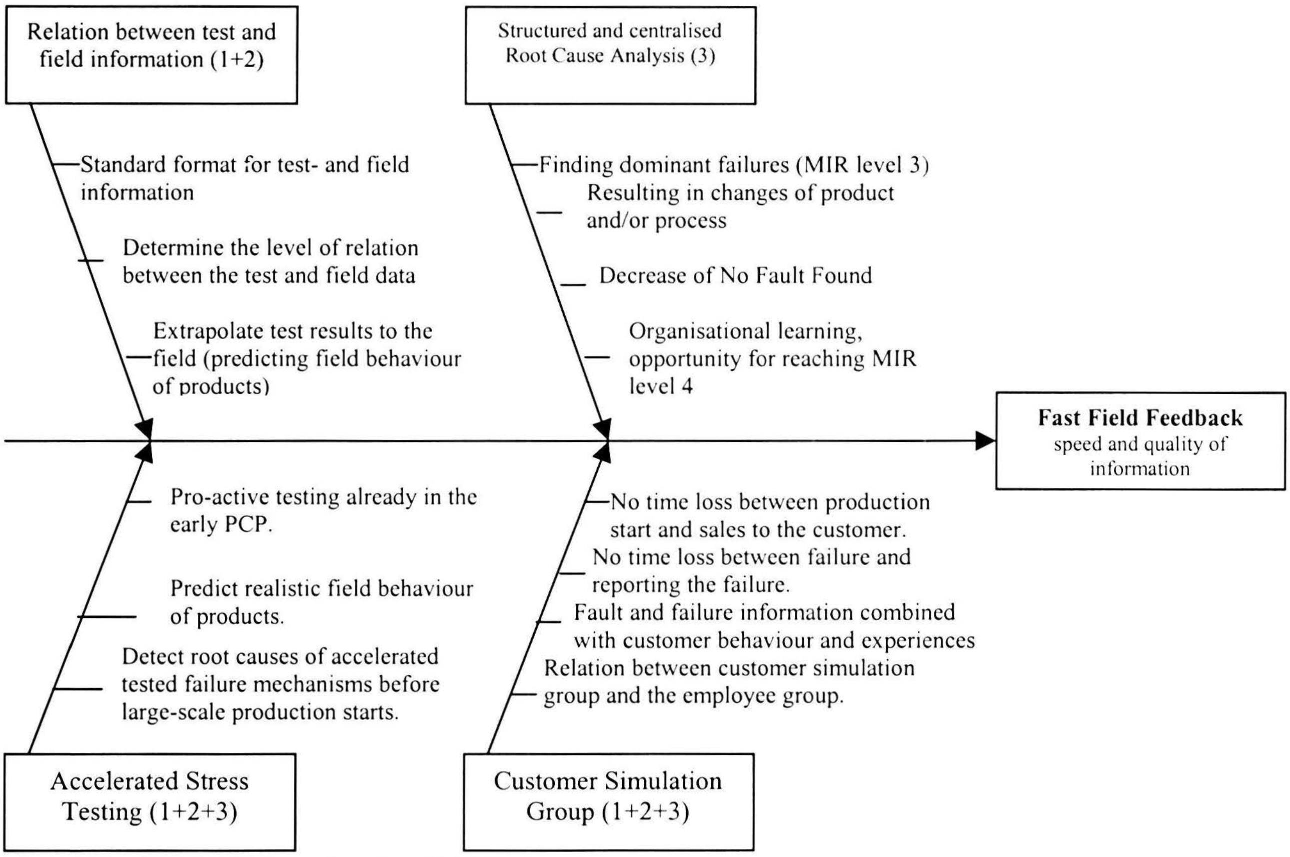


CASS, the contact for field feedback

5. Improvement alternatives

Improvement proposals are meant to solve some aspects of the Fast Field Feedback project. Improvement criteria (see in the fishbone between brackets):

1) Predict and/or prevent product failures in the field
2) Speed of field information
3) Quality of information suitable for performing an RCA



Alternatives within the thesis project Fast Field Feedback.

The Customer Simulation project has been selected because it shows best promise regarding the topic Fast Field Feedback.

6. Implementation plan

The goal of the Customer Simulation project is twofold. Both goals are pursued, however, the primary goal is given preference to the secondary goal.

Primary goal: Obtain fast quality and reliability related failure information from the customer simulation group describing the experiences of the trial products, in order to make improvements to the product and/or process before large-scale production starts.

Secondary goal: Determine whether the Simulation or existing Employee group reflect realistic customer behaviour. When the results are satisfactory (primary goal is obtained) and the Customer Simulation group reflects realistic customer behaviour, the group has to be made common practice within Bang & Olufsen. Future field behaviour can be predicted only when the results are product independent.

Information is available faster because:

- The time elapsing from Production Start to the moment of Sale to the customer has been skipped. The time lapse is caused by stock of finished products at Bang & Olufsen waiting for shipment, transport to and stock at the dealer (dependent on the stock of a possible predecessor), and the sales to the customer.
- Shorter communication line; the normal procedure of obtaining field information is through the channel from customer to dealer, dealer to NSO, NSO to CASS, CASS internally to the responsible persons/departments. The feedback loop of the Customer Simulation project is shortened by the direct contact of the Customer Simulation

participants with the contact agency. This is advantageous to the speed and completeness of the information.

Results for product quality (and reliability):

- To discover not anticipated quality risks of the new trial product, due to faults in product architecture, design, software or applied technology. Accordingly, improvements to the product can be developed and executed before the product launch will take place.
- The products from trial production, which are distributed to the simulation group are required to have the same specifications as the products that will be distributed to the market, otherwise prevention of symptoms that will not occur at the market is pursued.
- The hidden 0-hour failures and early wear-out problems will be discovered and, where possible, prevented from recurring before the product launch. Random failures are difficult to anticipate and the systematic wear-out failures will not occur in the (short lasting) customer simulation project.

7. Conclusions and recommendations

Conclusions

Bang & Olufsen is with regard to the Maturity Index on Reliability mainly at level 2. The availability of field data within Bang & Olufsen is high and the relevant data analysis techniques are systematically applied in the business process (MIR level 1). In general the location of failures, organisational place in the Product Creation Process and position within the product, is well determined (MIR level 2). Root Cause Analyses are performed in a less structured and systematic way, only for 'high impact' quality and reliability related problems an RCA is performed to find a solution and make changes and/or modifications to current products. So the business process is not able to generate detailed information on all dominant failures on root cause level and therefore Bang & Olufsen has not reached MIR level 3 yet. The proposed Customer Simulation project provides the first impulse to fast field feedback information suitable for use in performing RCAs and therefore the opportunity to reach MIR level 3.

The primary goal of the service process is servicing the customer and it is only partially assessed on its contribution to improvement of product quality and reliability. Only the Indicator Dealer program and the tasks of the Technical Product Managers are an example of contribution to product quality and reliability improvement, respectively gathering field information and coordination of handling the field problems. However, the main goal of service is still to help the customer as fast as possible and in a satisfactory way. The challenge is to achieve the right balance between servicing the customer, and in addition to this the task of contributing to quality and reliability improvement by providing field feedback information.

The *objective* of the graduation project has been stated at the start as:

> To develop an approach to improve and implement a rapid feedback structure on product and process quality and reliability failures. A well-established and formal programme organisation has to be developed to allocate and identify the root causes of quality & reliability issues at both business and technical process level.

The four improvement alternatives have much ground in common with the objective of the thesis project, however, the chosen Customer Simulation group fits the objective best because, when implemented, it provides fast feedback. And when the simulation group proves to reflect realistic customer behaviour the feedback given by the simulation group is similar to field feedback. The information facilitates a Root Cause Analysis, however, performing RCAs is ad-hoc based. Opportunity for further research is to structure and centralise the performing of RCAs for product failures from the field, final testing and production (see section 5.2.2).

Recommendations

- Execute the Customer Simulation project for a new product where not-anticipated quality and reliability risks can be expected. Choosing a mature product with familiar technology does not provide opportunity to improve. As guideline use the activities described in section 6.3. Evaluate the project on the added value to the primary and secondary goal it intended to achieve. This is translated in whether the feedback facilitates an RCA of the problems and whether re-design changes can be based on the feedback from the customer simulation group.
- Improve the current field feedback flows. Enlarging the number of Indicator Dealers to prevent missing important quality related field problems. And formalising the contacts in order to make the information as suitable as possible for an RCA, this means the complete product information combined with customers' experiences and product set-up.
  The availability target of the IRIS data has to be pursued to minimise the huge deviation from the target in some countries. The IRIS data have to be utilised in the normal working routine of repairing product failures and performing root cause analyses.
- Elaborate the learning cycles to secure the information within the complete Product Creation Process and preventing past problems from recurring. Change the learning loops from predominantly short-term reactive loops (problem solving within a department) to more pro-active long-term loops (anticipate quality risks through learning from the field).
- Change the test procedures because test strategies are not based on field information and therefore test-based predictions do not match with realistic product behaviour in the field. This is also caused by new technologies and increasing complexity of products.
- Develop knowledge management. The storage of know-how is limited at Product Development, re-design actions are not structurally documented, stored and shared within Bang & Olufsen what reduces organisational learning. And also individual learning because know-how is limited to the people involved in the re-design activities. This can be avoided by storage of this information in an organisation-shared database.

The recommendations are summarised in three "to-do" activities:

1. Implement the customer simulation group for a product where not-anticipated quality and reliability risks can be expected. Evaluate whether the intended goal of the customer simulation group is obtained.
2. Use the feedback from the customer simulation group for performing the root cause analysis of field problems. Accordingly a decrease of the number of No Fault Found is pursued and this is the base for reaching MIR level 3.
3. Ensure the information from field failures and the results of RCAs are documented, stored and shared within Bang & Olufsen. To achieve MIR level 4, this information has to be incorporated in the learning cycles and embedded in the Product Creation Process.

Acknowledgements

This report is the result of my graduation project performed as final part of my Masters degree in Industrial Engineering and Management Science at the Eindhoven University of Technology in the Netherlands. Finishing the report is the milestone that reflects the end of almost 5 1/2 year of study and the start of my career.
The graduation project has been executed in the period from end of February 2001 to the beginning of December 2001, and I have stayed the major part of this period in Denmark at the Bang & Olufsen headquarters in Struer.
I would like to thank Jeannette Hansen, my Bang & Olufsen supervisor, for her dedication and constructive support during the project. Together with her, I would thank the colleagues of the after sales service department for their assistance in my project and especially Jane, who had a hard job correcting my English.
I will always remember the pleasant talks and eating cake at Wednesday afternoon with the colleagues from department 7210.
From the university, especially Peter Sander as first supervisor and Valia Petkova as supporting PhD student coached me to keep on track. I would like to thank both of them, together with second supervisor Jan Rouvroye, for their vital contribution to a successful result.

Without the persons I mentioned with their support and advice, it would not have been possible to accomplish this graduation project. Looking back, working and living in a foreign culture has broadened and enlightened my view on many issues and an experience I will cherish the rest of my life.

Wijnand van Dommelen

December 2001

Table of contents

1. Introduction

The overall structure of the report is an introduction to the project (Chapter 1), Bang & Olufsen in general (Chapter 2), the literature with respect to Fast Field Feedback and Root Cause Analysis (Chapter 3), fact and figures with respect to Fast Field Feedback and Root Cause Analysis at Bang & Olufsen followed by an analysis (Chapter 4), improvement alternatives and a proposal for a new structure (Chapter 5), an implementation plan (Chapter 6), and conclusions and recommendations (Chapter 7).

1.1 Introduction

This chapter introduces in detail the background of the project and states the objective, expected results, deliverables and scope of the project. Furthermore this chapter describes the plan of approach to attain the objectives.

1.2 Project

An aspect of improving the quality and reliability of products and processes is to improve the use of information from the market. The market information is quality and reliability related information about the behaviour of the products in the market. To fully utilise this information it needs to be available fast and in a suitable form for a root cause analysis (RCA). This resulted in the project with the following objective, expected results, deliverables and scope.

- Objective

The objective of the project is to develop an approach to improve and implement a rapid feedback structure on product and process quality and reliability failures. A well-established and formal programme organisation has to be developed to allocate and identify the root causes of quality & reliability issues at both business and technical process level.

- Result

The result of the project will be:
- A flow diagram for Fast Field Feedback.
- A description of activities required for defining, implementing, and executing the feedback structure, focusing on root cause analysis.

- Deliverables

The deliverables of the project will be the case description with a presentation and implementation of the Fast Field Feedback Structure.

- Project scope

The scope and boundaries of the thesis project are limited to:
- An audio/video product, including the interfaces with its customers. The development and manufacturing of telephone and medical products have other characteristics than the audio/video products, although the distribution of telephones is mostly through the same channels as those of the audio/video products.
- The topic of fast field feedback covers the gathering and processing of field information about products at Bang & Olufsen. The project will strongly focus on the gathering and processing of field information, and especially the time and root cause aspects are considered. The internal actions that are undertaken in relation to the field information are given less attention.

1.3 The way of approach

This section describes the activities and tasks performed to change the present situation to a desired future situation. This is represented in figure 1 by the objective, the executed activities, and the results and deliverables of the graduation project.

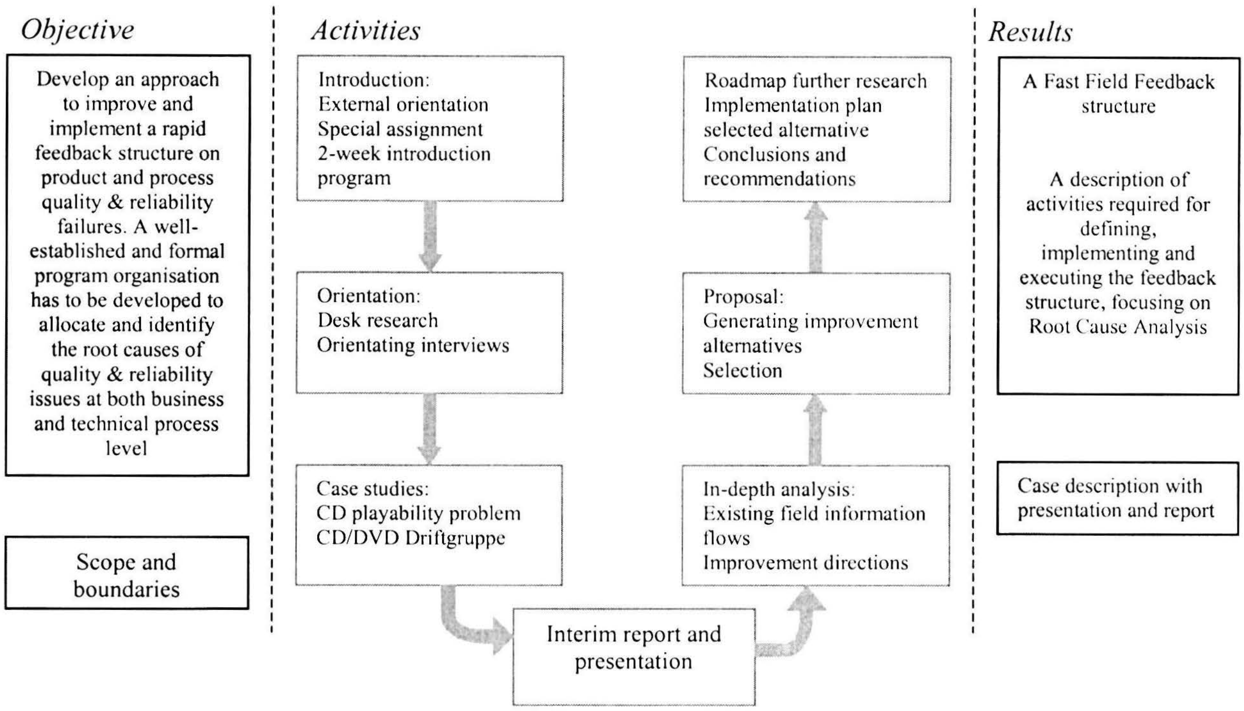


Fig 1: Research activities

The results and deliverables of the Fast Field Feedback structure are translated in a number of improvement goals:

- Decrease in the number of No Fault Found (NFF)
- Reaching Maturity Index on Reliability level 3, opportunity for MIR 4
- Improvements to running products and/or production process
- Learning from previous product quality & reliability problems
- Predicting future field behaviour
- Anticipating future product quality & reliability risks

1.4 Summary

In this chapter the graduation project "Fast Field Feedback" has been described in general. In the remainder of the report the different chapters describe the project in more detail. Chapter 2 is about Bang & Olufsen in general and how the project fits in. Chapter 3 handles the relevant literature used in the project. Chapter 4 describes the facts and figures with respect to Fast Field Feedback, and especially the "time" and "root cause" aspects are considered. Also the analysis of the facts and figures with respect to whether the field feedback is the right information and whether it is fast enough will be given. In chapter 5 some improvement alternatives are proposed to solve part of the problems found in the previous chapter. Chapter 6 describes how the changes should be implemented and in addition the conclusions and recommendations will be given in chapter 7.

2. Bang & Olufsen in general

The vision of Bang & Olufsen is "Courage to constantly question the ordinary in search of surprising, long lasting experiences" [29].
The vision provides a set of guiding principles for all the employees. It is dynamically expressed in the working methods and in the way Bang & Olufsen deals with others. It boldly manifests itself in all the communication, and achieves its ultimate expression through the products.
The vision is rooted in the values of Bang & Olufsen: poetry, excellence and synthesis.
In relation to the vision and values of Bang & Olufsen the graduation project fast field feedback fits in the organisation. Bang & Olufsen wants to excel, and at least be among the best, in every aspect of quality. Gathering field information, analysing and communicating the information and in this way make re-design and learning possible are all related to quality and especially the quality of service and products.
This chapter gives a short introduction of Bang & Olufsen; description of the products, its organisation, some relevant developments, the after sales department and the information sources regarding field feedback.

2.1 Introduction

Bang and Olufsen is a consumer electronics manufacturer, founded in 1925 and located in Struer, Denmark. In the last financial year (June 2000- May 2001) the turnover equalled 3,810 million DKK [24] and the pre-tax results were DKK 224 million. Bang & Olufsen employs 2780 full time employees, of which the major part is located in Struer.

2.2 Products

Bang & Olufsen develops, manufactures and sells high-end video, audio and telecom products for the consumer market, furthermore it manufactures products for the medical market.
Recently it has also expanded into new areas, such as car stereo and multimedia products. The products, which Bang & Olufsen puts on the market, are particularly well known for the design.

Table 1. The current product range of Bang & Olufsen

Music systems	Televisions	Loud-speakers	Integrated products	BeoLink	Tele-phones	Accessories
-BeoSound 1 -BeoSound 3000 -BeoSound 9000 -BeoSound Century -BeoSound Ouverture -BeoSound 2	-BeoCord V8000 -BeoVision 1 -BeoVision Avant -BeoVision Avant US -BeoVision MX -DVD1	-BeoLab 1 -BeoLab 2500 -BeoLab 4000 -BeoLab 6000 -BeoLab 8000 -BeoLab 2	-BeoCenter 1 -BeoCenter AV5	-Beo 4 -BeoLab 2000, 3500 -BeoLink PC 2 -BeoVision 1LS -BeoVision MX 4002 -LC2	-BeoCom 1401, 1600, 2500, 6000 -BeoTalk 1200 -BeoCom 2 -BeoCom 3	-Earphones -Form 2 -Key ring

2.3 Organisation

Bang & Olufsen has implemented a different organisational structure (fig. 2), the different parts of the Bang & Olufsen United structure are:

- *Bang & Olufsen a/s*

Develops and strengthens the brand –in close cooperation with Idealand (product concepts), StoryLab (communication concepts) and New Tech (the technology function). Bang & Olufsen a/s also comprises group staff functions such as HR, IT and PR as well as law, finance and quality assurance.

- *Bang & Olufsen AudioVisual a/s*

Focuses on development, sales and distribution of Bang & Olufsen A/V products, including the new retail initiatives in the US. In the coming years, the audio/video business will continue to account for the predominant share of Bang & Olufsen's turnover and earnings.

- *Bang & Olufsen Multimedia a/s*

Ensures the ongoing development of the company's general Internet competencies. As a first step, DKK 40 million has been invested in multimedia activities.

- *Bang & Olufsen Telecom a/s*

Develops telephony concepts for electronic communication in the home.

- *Bang & Olufsen Medicom a/s*

Develops its concept competencies in the field of acoustics, miniature electronics and precision mechanical engineering in close collaboration with existing and new partners.

- *Bang & Olufsen New Business a/s*

Comprises two business areas; research and development of acoustics and the continued development and commercialisation of car entertainment systems for the automotive industry.

- *Bang & Olufsen Powerhouse a/s*

Develops and explores the wide range of ICEpower® applications. ICEpower® aims for ideal audio power conversion.

- *Bang & Olufsen Operations a/s*

Handles all production, logistics and purchasing.

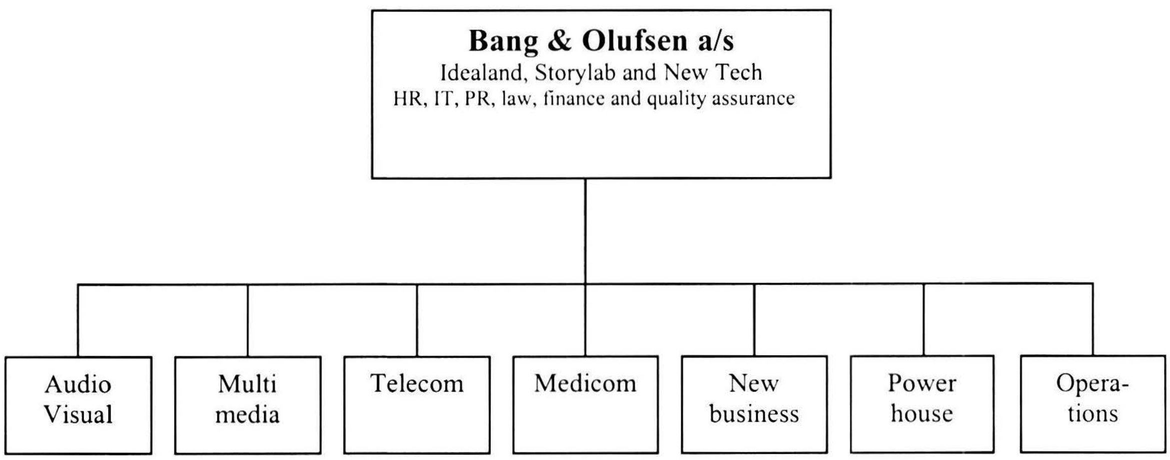


Fig. 2: Bang & Olufsen United structure

2.4 Branch and company developments

- Globalisation

Bang & Olufsen exports 76% of the production, and the globalisation of the market increases this part. New markets for Bang & Olufsen with strong growth potential are for example the USA and the (Asian) Expansion Markets.

- Distribution network, B1 dealers

The development during the last years confirms Bang & Olufsen's distribution strategy. In markets with relatively few multibrand shops, the opening of dedicated Bang & Olufsen (B1) shops has resulted in significant growth from year one. However, in the large established markets Germany, Switzerland and Denmark, a re-organisation of the very large number of multibrand shops proved necessary before it was possible to persuade enough new dealers to invest in B1 shops.
As of May 31, 2001 Bang & Olufsen sold its products in 2017 shops across the world compared to 2,172 the previous year. Bang & Olufsen has opened 101 dedicated B1 shops resulting in a total number of 530 B1 dealers.
The present distribution strategy will be maintained and this will be achieved by opening B1 shops, upgrading multibrand shops through shop-in-shop solutions and terminating agreements with a limited number of smaller multibrand shops.

- Retail Ordering System

During the last few years, Bang & Olufsen has set up an internet-based Retail System, linking all dealers and service centres to the corporate headquarters in Struer. The system not only means administrative efficiency in connection with on-line order processing, but will also result in a far closer dialogue between the individual shops and Bang & Olufsen. This will also provide greater opportunities to service customers. The system not only entails faster order processing, in the long term Bang & Olufsen in Struer will be able to keep dealers fully informed about new products, marketing initiatives and general developments. With regard to field information a similar or elaborated structure of the retail system can provide Bang & Olufsen with field feedback. The Indicator Dealer program and the Customer Satisfaction Index (measuring the satisfaction of the customer regarding repairs) are already available at the retail system for the involved dealers.

- Product Launches

An important issue of a company in the consumer electronics market is the launching of new products. Every year it is expected that a new product concept or next generation products will be launched. The development of a new product takes a lot of effort and therefore money, without the certainty of the new product being profitable. The latest product launch is the BeoLab 2, a loudspeaker where the ICE power technology is used in. The product launches in the last financial year were:

- BeoCom 2; a cordless telephone.
- BeoCom 3; the first 100 percent ISDN telephone of Bang & Olufsen with 2 lines.
- BeoCenter 1; a compact sound and picture centre comprising a 25" television, a combined CD and DVD player, FM radio and 2 active loudspeakers.
- DVD 1; a stand-alone DVD player.
- BeoSound 1; a portable radio, with CD player and 2 active loudspeakers.

2.5 Corporate After Sales Service

The after sales service department has the contact with the customer and is therefore potentially the most important contributor to quality improvement. In this paragraph the Corporate After Sales Service of Bang & Olufsen (CASS) will be discussed covering the relevant issues regarding field information.

CASS is the department between the distribution and engineering at Bang & Olufsen, what means that engineering uses the market feedback to improve the quality of Bang & Olufsen its products (see fig.3) [18].

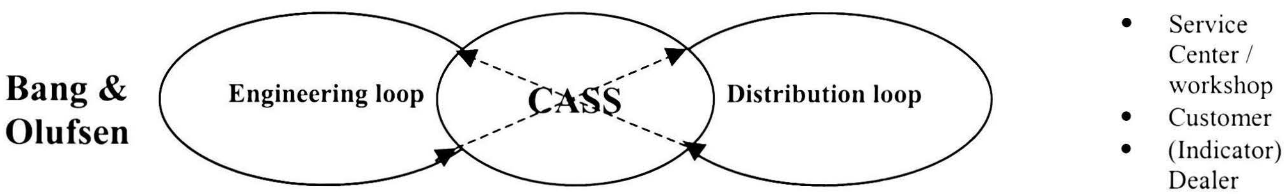


Fig. 3: Learning loop of *Product Quality* at CASS

- Distribution loop (see fig.3) [18]

The distribution gets quality information from market feedback. The feedback information consists of:
- IRIS Repair data
- (Indicator) dealer
- Customer contact
- Network feedback

At the CASS meeting a Market Quality report is generated, the contents are TOP10 lists of product deviations and issues on Quality development.

- Engineering loop

The Engineering loop uses the Market Quality report as input, and in particular TOP10 Q-problems that are divided into:
- Potential problem indicators, visible only as indicators but with a risk of growing.
- Present problems that are currently engineered for a solution.
- Past problems that have been solved in production, product development and service, however the problem still remains in some products on the market.

The output is activities, which need to be undertaken by Purchasing, Production, Product Development and Service. Distribution in turn uses the activities and new market field feedback as input and the loop continues.

2.6 Different information sources

A number of parts within the after sales service receive field information. This section describes the Indicator Dealer Quality (IDQ) program, the IRIS repair data, the Customer Contact Centre and the National Sales Organisation.

2.6.1 IDQ

The Indicator Dealer Quality Program was started two years ago to obtain a direct indication of the "heartbeat" in the indicator dealer shops to get immediate knowledge of the most important problems at the moment. It is an additional way to get fast field information and it is not a substitute for normal communication and business routines. Seventeen dealers from Denmark, United Kingdom, United States of America, Singapore and Australia take part in the program.

The Indicator Dealer Program is part of the new online Retail System but only the indicator dealers and the IDQ contact centre have access to it. Objective as well as subjective information about quality related issues are included in the Indicator Dealer Program. However, the feedback must describe the customer experience/disappointment concerning product-related subjects.

The Indicator Dealer program was started with a focus on Quality-related issues. The plan, however, is to expand the project with more issues and more Indicator Dealers in the future, such as Logistics, Marketing, and Service. The program is now being expanded with issues within logistics, such as ordering/backordering, transport and packing.

2.6.2 Repair information, IRIS

In order to get a warranty claim approved the dealer or workshop has to fill in the IRIS (International Repair Information System) repair codes. The IRIS coding consist of two areas:
- The symptom area describes the set's malfunction as perceived by the user. It requires no specific technical know-how to be filled in, and it uses the *condition* and *symptom* code.
- The diagnosis area is intended for the technician to describe where the fault was located, and the actions that were taken by him to repair the product. It uses the *section* code, *part references*, *defect* codes, *repair* codes and a *repair flag* [30].

A small part of the IRIS codes covers the claims after the warranty period, especially in connection with 'fairness repairs'.
Fairness is an individual compensation for customers, who react on a relevant gap between expectation to the brand and the service provided. In figure 4 the information flow of a repair to Data storage in FQI (Field Quality Information) is explained.

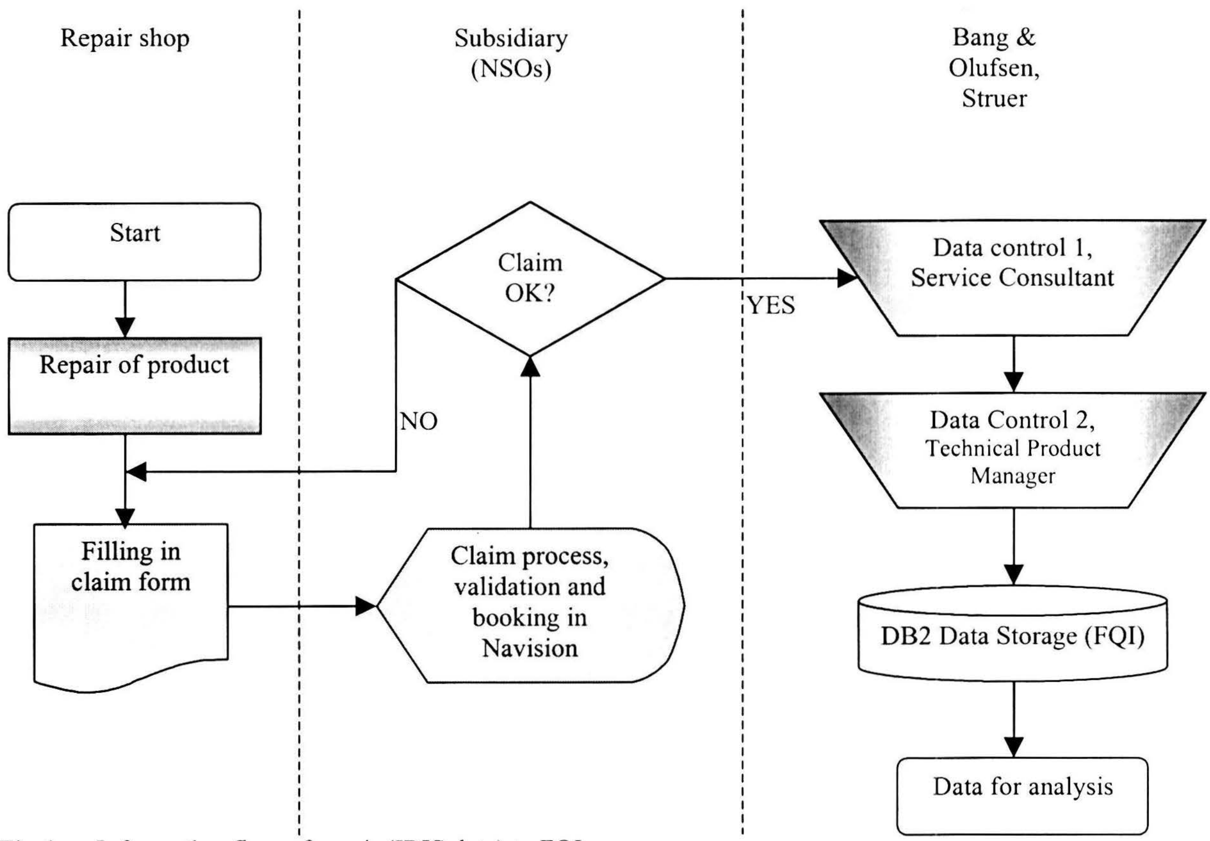


Fig 4: Information flow of repair (IRIS data) to FQI

2.6.3 Customer Contact Centre

The Customer Contact Centre (see app. H) communicates with the customers via email, fax, letters and phone calls. The major part of the contacts is per email (95 %), and the volume is expected to increase in the future. The inquiries are categorised in a number of groups: product commercial, product technical, documentation, direct purchase, future products, complaints, praise and miscellaneous.

The aim of the CCC is to respond to inquiries within one day for emails, a two-day time period for faxes, 5 working days for letters and immediately for phone calls (longer when it is necessary to search for an answer or solution).

The primary goal of the CCC is to provide a complete service whenever a customer demands for it within the before mentioned time frame. An additional result is that a part of the contacts will provide information about products of Bang & Olufsen in the market. This feedback can give an indication of (potential) field problems.

2.6.4 National Sales Organisation Denmark

The structure (fig. 5) of the national sales organisations in the different countries has specific characteristics as has the organisation of the dealers with or without their own workshop, workshop (only repairing), service centre and a competence centre.

The dealers are divided into dedicated Bang & Olufsen (so called B1) dealers, multibrand shops and shop-in-shop solutions. Bang & Olufsen distribution strategy is to focus on the opening of B1 dealers. But especially in the mature markets these B1 dealers are still a minor part of the total number of shops.

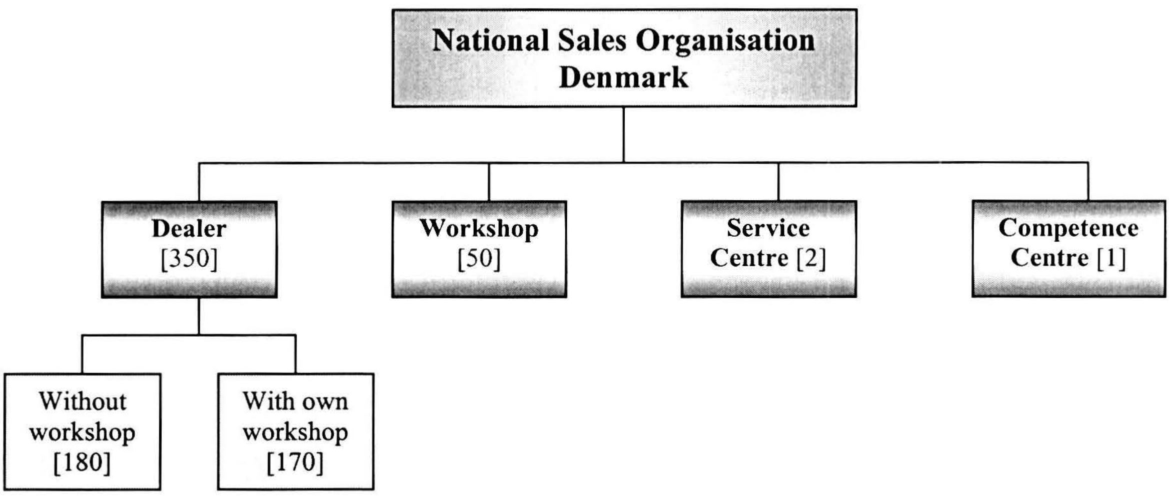


Fig 5: National Sales Organisation Denmark

2.7 Summary

This chapter gave some characteristics of Bang & Olufsen to provide a general understanding of the company. Also the after sales service department and the information sources regarding field feedback are introduced. The next chapter describes the literature that is relevant with regard to the topic of field feedback information and suitability for a root cause analysis. The literature is compared with the current situation of Bang & Olufsen.

3. Literature

This chapter gives a first introduction to definitions and relevant issues with respect to Fast Field Feedback and Root Cause Analysis, the Maturity Index on Reliability, the Plan-Do-Check-Act cycle, and Product Quality Improvement.

3.1 Fast Field feedback

The theory of "Fast Field Feedback" and "Root Causes Analysis" will be described in this section. The literature will be discussed with respect to the situation and the relevance to Bang & Olufsen.

At first a few definitions that are used throughout the whole report will be presented:

- *Reliability*

The reliability of a product is defined as the ability of a product to deliver its intended functions over a stated period of time [11]. Lewis defines reliability as "the ability of a product or system to fulfil its intended purpose for a certain period of time"[12].

- *Quality*

Classically, quality has been defined as the extent in which the product at deliverance conforms to the technical specification [13].
Lewis states quality as "the ability of a product to fulfil its intended purpose" [12].

- *Root causes*

The root cause is the most basic reason for an undesirable condition or problem, which, if eliminated or corrected, would have prevented it from existing or occurring [9]. Information on root cause level is detailed data that will lead to all dominant failures. This can be translated into repairs/modifications in current products and anticipated risks in future products [2].
Andersen & Fagerhaug [5] state, "The root cause is 'the evil at the bottom' that sets in motion the cause-and-effect chain that creates the problem(s)."

- *Root cause analysis*

A variety of techniques, both informal and structural, that may be used to determine the (root) causes. The testing of failed products as regards functions and parameters is a (ad-hoc) method to determine the (technical) root causes.
Andersen & Fagerhaug [5] state "Root Cause Analysis is a structured investigation that aims to identify the true cause of a problem, and the actions necessary to eliminate it"

- *Field Feedback information*

Field Feedback is information from the market of the time moment a customer perceives a problem and contacts Bang & Olufsen. The focus with regard to field information is on the first contact between the customers who have a problem and the dealer, service centre or NSO, to the moment the After Sales Service department is informed.

- *Product Creation Process*

A production creation process (PCP) start with the perception of market needs and ends with the introduction of a new or improved product [17]. However, regarding quality and reliability, customer use and after sales service are also included in the Product Creation Process.

3.2 Using the field feedback information

Service centres are the closest contact to the market regarding repairs and failures so they are the most suitable for obtaining information from the field. If the behaviour of products in interaction with the customer is well-analysed and communicated, recurrence of old problems in new products can be avoided [3]. However, it is impossible to predict and prevent all quality and reliability risks in the design, development and production phases. In this respect it is important to get information about the field behaviour of products as soon as possible after product launch to make necessary changes and modifications due to not-anticipated quality and reliability risks.

In order to learn from field problems and to use this information in next product generations and also to make changes in current products a few issues are important:

1. Getting the right field feedback at the right moment. The right information concerns quality/reliability oriented information that facilitates performing the root cause analysis and can be used to improve product quality and reliability. The right moment means fast enough given the Product Creation Process (for anticipating risks in next generation products) and the Product Improvement Process (for changes and/or modifications to current products).

2. Processing the field feedback information means to analyse the information and communicate the relevant information to the involved parties within the organisation. This is the activity that follows after the gathering of field feedback.
   The analysis consists of structuring the information and filtering out less relevant data. The structured and filtered information can be used directly by the involved parties, like Product Development in case of re-design activities.

The fast generating of new technologies and products results in products unable to achieve design stability or production maturity before a given product type becomes obsolete [4]. This results in difficulty of accumulating stable failure data to permit confident comparison with prediction or form a useful base for future predictions. The problem is worsened by the parallel trend towards a short lead-time to market, which reduces the time available for pre-release or pre-shipment testing and reliability measurement. This makes it difficult for the supplier to provide comprehensive and narrow confidence interval reliability information to the customer.

Sander and Brombacher [1] say about this issue that the high innovation speed has the consequence that the product is no longer in production by the time field information becomes available. If field information on a product of generation 1 is collected during the production of a product of generation 2, then corrective actions can be applied in generation 3 and only to a limited extent in generation 2. Preventive actions can be applied in generation 4 and only to a limited extent in generation 3 (fig.6).

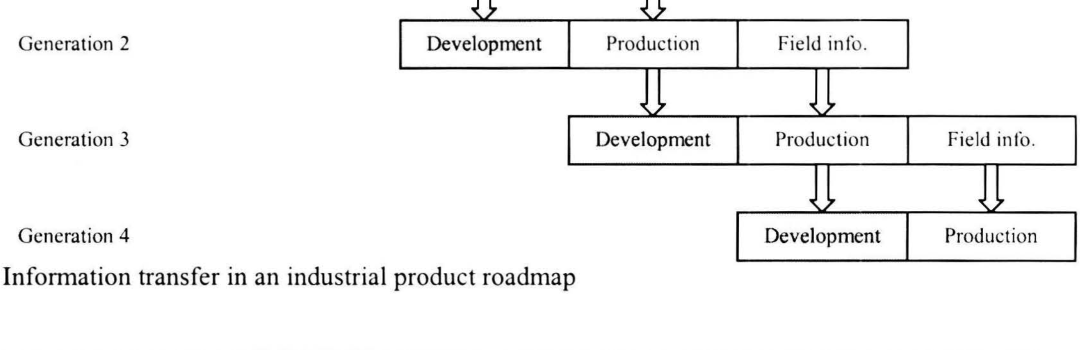


Fig 6: Information transfer in an industrial product roadmap

However, in comparison with other Consumer Electronics Manufacturers (CEMs), the products of Bang & Olufsen have longer Product Life Cycles. Accordingly the time periods for the development, production and after-sales-service phases are longer. This results in the fact that the problem of getting the field feedback at the right moment for preventive actions (improvements) in next product generations is smaller at Bang & Olufsen. The right moment to take corrective actions (modifications/changes) to running products, however, demands a close follow-up after product launch to gather failure information.

Whether the information is fast enough to avoid problems in next product generations depends on the length of the Product Life Cycle; the development, production and customer-use phase. When the development phase has started (or even finished and the next generation product is already in production) before specific faults in the field occur, the possibility of anticipating these faults has decreased considerably.

3.3 Maturity Index on Reliability

This section describes reliability, the Maturity Index on Reliability (MIR) model and the MIR status of Bang & Olufsen.

3.3.1 Reliability

The aim within Bang & Olufsen is to divide the product quality and reliability faults in; design faults, component faults and process faults (fig. 7). These categories are directly related to the PCP (product creation process), respectively the design phase, the (supplier's) component production and assembly. Interaction problems between product and customer use are not incorporated in the triangle.

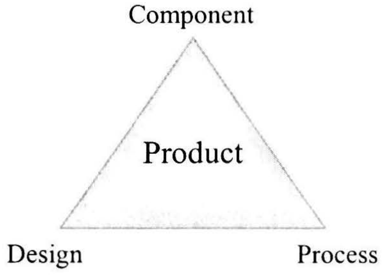


Fig. 7: Reliability aspects within Bang & Olufsen

An ad-hoc based Root Causes Analysis is only performed when a field problem occurs with a high impact in the market. No (central) testing department is in place at Bang & Olufsen performing a structured Root Causes Analysis of the returned failures from the field. External Quality Control calculates the ppm (parts per million) rates of supplied components and modules and it also performs some rough tests to supplied components and modules. The development department tests products from the market when a possible re-design is needed. Although only little valid and statistical information is available the amount of NFF (No Fault Found) exceeds certainly half of the performed RCAs, and this is in line with the expectations of the research results [13] (fig. 8).

The trends regarding consumer electronics are a high pressure at time-to-market, increasing complexity in both product and production process, and the increasing consumer demands with respect to a higher product quality and reliability.
In line with the trends, the expectation is that an increasing number of "no fault found" will be a dominant factor in future product reliability [13] (fig. 8), and in this respect the topics Fast Field Feedback and Root Causes Analysis are important for Bang & Olufsen.

The After Sales Service already focuses on the customer guidance and the dialogue with the customer to decrease the faults due to customer use and to assess the degree of satisfaction of the customer. However the increasing number of "No Fault Found" requires attention to Fast Field Feedback and especially information suitable for a Root Causes Analysis.

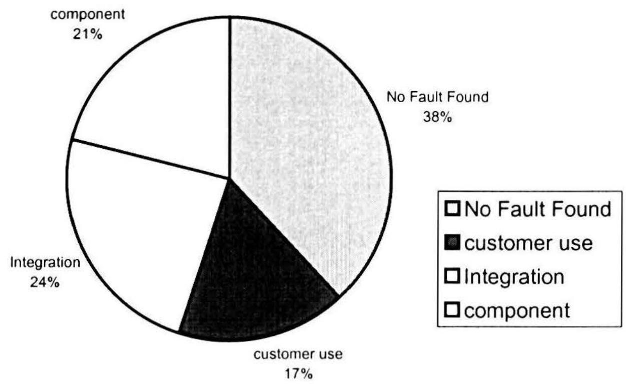


Fig. 8: Categories of Reliability faults

3.3.2 MIR model

The MIR assessment [9] is a tool used to measure and improve the quality of the reliability-related information in the control loop (technical aspect) and the deployment of this information into the business processes (organisational).

A development in the field of reliability is the realisation that this aspect is not only a function of the product itself, but also of the organisation realising the product.

A second development is a trend from an often predominantly qualitative analysis towards a quantitative analysis. The basic difference between the quantitative and the qualitative aspects can be found by looking at the corresponding questions:
-Qualitative: are certain requirements fulfilled, for instance the ISO 9000 standard.
-Quantitative: how well are these requirements fulfilled, for instance fault trees.
On product level the development means also a quantitative analysis and, on organisational level, an assessment of the entire life cycle on the (maturity of the) business processes and how these processes are maintained.

As mentioned before, analysing the reliability or safety of a product will require not only the analysis of the technical aspects of a product, but also the analysis of the (quality of the) reliability control loop of the organisations developing and operating a product. The quality of the reliability control loop can be measured in two aspects:

- The quality of the reliability related information in this loop; and
- The deployment of this information into the business processes.

In order to measure these aspects, the MIR concept [9] is used (fig. 9). This scale of four levels reflects the increasing capability of an organisation to analyse, predict and improve the reliability of current and future products. The four MIR levels are defined as:

1. Quantification (measured): The business process is able to generate quantitative information, on a *per product* basis, indicating the number of failures in the field and production.

2. Identification (analysed): The business process is able to determine the primary and secondary location of failures:
    - Primary (organisation): location of the cause of the failure within the business process (Development, Production, Operation, etc.)
    - Secondary (position): location of the failure within the product (Hardware, Software, etc.).
3. Cause (controlled): The business process is able to generate detailed information for all dominant failures on root cause level. This can be translated into repairs/modifications in current products and anticipated risks for future products.
4. Improvement (continuous improvement): The business process is able to learn from the past by installing business processes and working methods to anticipate reliability risks for future products and eliminate these risks as part of a new product creation.

In order to qualify for a maturity level *n*, the requirements of level *n-1* and lower have to be fulfilled.

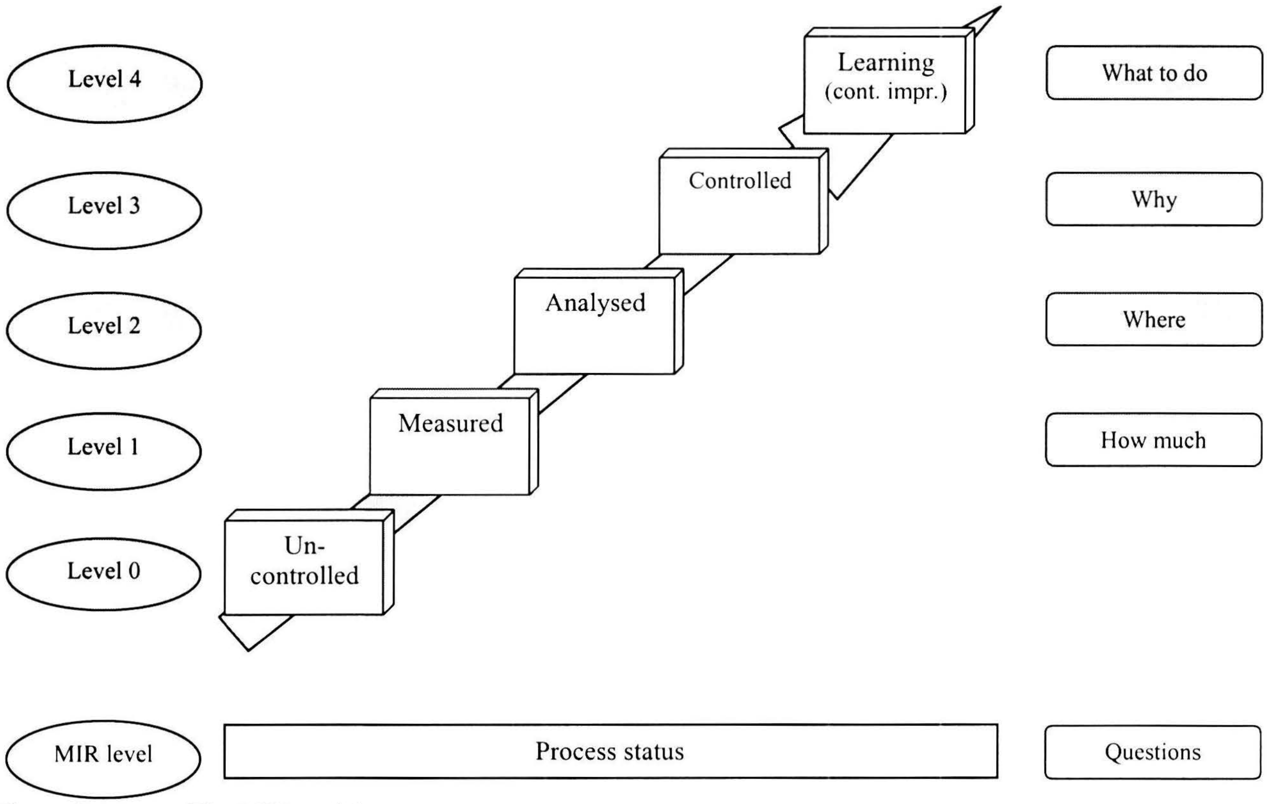


Figure 9: The MIR model

3.3.3 MIR status Bang & Olufsen

\- MIR 1: Information about failures from the field is for example the IRIS repair data. These repair data are used for calculating the Call Rate for the individual products. Indicator Dealer Quality information is quality related product information directly from a few selected dealers.
Production failure information is provided by KVP (faults registered in processes of electronics, mechanics and assembly) and KVF (faults registered at customer control; initial test, CSP (continuous sampling plan) and burn-in) [22,23,28] (app. A and D).

\- MIR 2: The IRIS data are used by Module and Product repair to find the location of failures and to solve the fault. Field information that is analysed and used by Bang & Olufsen's processes to find the primary and secondary location of faults is at MIR level 2.

- MIR 3: Bang & Olufsen is able to generate detailed information about a part of the dominant root causes, but not for all failures. The supplier also has a role in it, because component or modules delivered by suppliers may also cause products to fail. An example is the laser corrosion; information is available but not on root cause level (even not at the supplier) so the fault is still unsolved and failures still occur in the market. The CD playability problem is an example of cooperation with the supplier where the root cause has been found, the fault solved and product modifications implemented. The gathered information is used for anticipating risks for future products, however not-known problems may always occur.
Bang & Olufsen is working and focusing on MIR level 3 but has not achieved it yet.

- MIR 4: This level is not reached because the lower level requirements have to be fulfilled first.

Existing information loops at Bang & Olufsen:

- *Component management*: The failure rates of out-of-spec supplied modules and components that are detected by testing the purchased modules or by failures in the production are fed back to the supplier. The allocation of these failures is done by the supplier or in cooperation with Bang & Olufsen when it involves critical supplied components. The business process is not always able to generate information on root cause level, so MIR level 2 is achieved (app. G).
- *Quality production management*: Faults in production are analysed and improvements are performed. The technical root cause is investigated, but the organisational cause of failure only to a limited extent. For example when it is difficult to assemble particular parts of a product; the common way is trying to make more effective assembly steps, however, Product Development could have caused the problem by complicated product architecture.
- *Test results management*: The failures of finished products at testing (CSP, LTAP, burn-in) are analysed and fed back to the responsible production, supplier or development activities. Too often, testing is just removing the rejects, instead of solving the cause of the reject where it occurred in the PCP.
- *Field failure management*: This is the most important loop (see section 3.5) with regard to Fast Field Feedback and Root Cause Analysis. The (high impact) product failures from the field are analysed on the organisational and technical root cause. The information needs to be fed back to the responsible departments and actions (re-design / learning / service solutions) initiated.

The quality of the information loop consists of the quality of the information and the deployment of the information in the business processes.
Although these processes have a MIR level 2 (and partly even MIR level 3), the control loops are not completely embedded in the Product Creation Process. Therefore the deployment and validation of the available information is not fully utilised and in general Bang & Olufsen is at MIR level 2.

3.4 The Deming PDCA cycle

The Deming PDCA (Plan-Do-Check-Act) cycle [6, 7, 14] is useful for structuring the goals, describing the present situation and causes of the problem, developing and implementing changes and reviewing the results.

Plan

1. Select the problem/process that will be addressed first (or next) and describe the improvement opportunity.
2. Describe the current process surrounding the improvement opportunity.
3. Describe all of the possible causes of the problem and agree on the root cause(s).
4. Develop an effective and workable solution and action plan, including targets for improvement.

Do

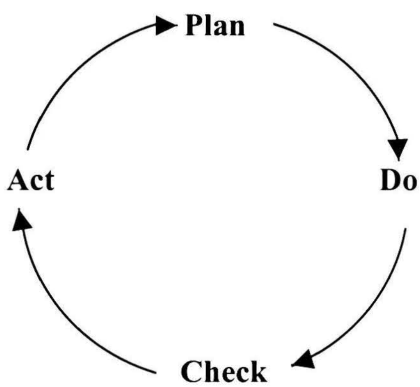
5. Implement the solution or process change.

Check

6. Review and evaluate the result of the change

Act

7. Reflect and act on the learning.



Plan: What to achieve?

Develop a method or new structure that will provide an easy-to-use tool for gathering and representing field feedback information faster and in a more suitable way for performing Root Cause Analyses in order to achieve a decrease in the number of No Fault Found.

Fig. 10: The Deming PDCA cycle

The thesis project focuses especially at the "Plan" phase of the Deming cycle. At first the problem issues regarding the topic of the project are identified, the relevant processes within Bang & Olufsen are analysed, and an improvement is proposed that can solve (part of) the problem issues regarding the speed and quality of field feedback information.

3.5 Product quality improvement

The service department has an important role in gathering and processing the market information that makes learning and quality improvement possible. The role of the service department and the reactive learning cycle will be described in this section.

1. Role of service centres in quality improvement

The contact between a customer and the manufacturer is via the retailer when a customer has a complaint or product failure. In particular when the fault is covered by the warranty, the service centre will try to repair the product as fast as possible and with minimum cost. Service centres will try to reduce local costs by skipping expensive and locally non-contributing activities. If a service centre is not assessed on its contribution to quality improvement, it has no motive to spend time on finding the root cause of the customer's problem and to communicate this to the other parties in the PCP (Product Creation Process). Consequently, there is no information flow from service centres to the other parties, the only information exchange between designers and service centres concerns the serviceability of the products. As far as service is concerned, replacing the failing modules or the product solves the problem [3].

2. <u>The reactive learning curve for product quality</u>

The levels of Quality with focus on the customer (fig. 11)[31]:

Level 0: Effective and individual handling of the customer's product problem.
Level 1: Fast and informative market feedback.
Level 2: Fast and effective data handling and analysis.
Level 3: Actions and responsibilities

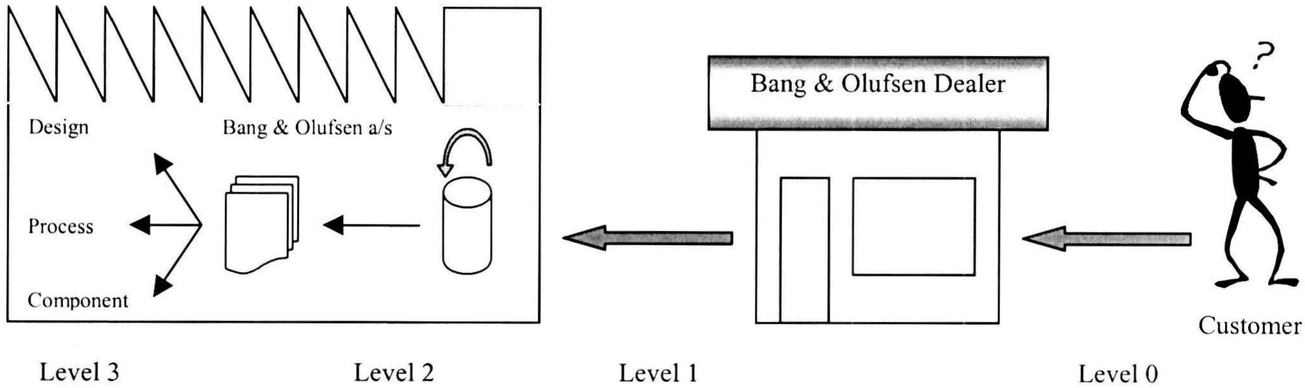


Fig. 11: Reactive learning curve for product quality

The different levels in relation to time and root cause aspects

Level 0: This level represents the primary purpose of the After Sales Service department. Important in this aspect is the response- and repair time of calls and the traceability of the original customer in case of recalls (products with failures called in for repair).

Level 1: The symptom-related failure reports are available at Bang & Olufsen on a daily basis (IDQ). The repair data (IRIS) is required to be available for a major part within 2 weeks and complete within 4 weeks. Another aspect of the market feedback is elaborate and valid information about customer experiences, product set-up and customer use.
This level is the most important with respect to Fast Field Feedback and suitability for Root Causes Analysis. The product related (symptom) reports (IDQ), repair data (IRIS) and the elaborate information about customer experiences and circumstances give information that facilitates a Root Causes Analysis. On condition the information is valid, complete and available within a short time frame.

Level 2: This level comprises the internal handling of data into information and the analysis of the failure symptoms to causes (root cause analysis). With respect to RCA a decrease in the number of No Fault Found of the returned products from the market is important. The CD/DVD Driftgruppe (appendix I) is working especially at this level.

Level 3: Information and root causes are used to execute needed follow-up actions by assigning responsible persons and departments. This level is valuable for the use of the field feedback in the organisation's improvement processes, however, the project focuses especially on level 1 and 2.

Conclusion
Level 0 of the reactive learning curve (fig. 11) is the most important with regard to the goal of the Corporate After Sales Service department of Bang & Olufsen, namely " to provide a complete service, wherever and whenever the customers meet us".
However, the service department of Bang & Olufsen (CASS) is also assessed on its contribution to quality improvement. CASS is responsible for gathering the market feedback of product related issues at level 1 and for handling, analysing and communicating these data at level 2. At level 3 the actual execution of follow-up activities is the task of re-design and re-engineering.

3.6 Summary

This chapter has described some literature that has been published in the scope of using field information to facilitate a root cause analysis, in order to make changes in running products and anticipate quality & reliability risks in next product generations.
The next chapter describes in detail the field information used at present within Bang & Olufsen, and the analysis regarding time and root cause aspects.

4. Field Feedback within Bang & Olufsen

The present situation describes the different sources of field information at Bang & Olufsen regarding time and root cause aspects. The analysis gives a judgment about whether this field feedback is fast enough for re-design of running products and for anticipating quality and reliability risks in next generation products. The field feedback is also analysed on its value for a root cause analysis.

4.1 Introduction

CASS is the closest contact in Bang & Olufsen to the market with regard to after sales service information (fig. 12), and the most suitable for getting product related failure information from the field. The focus will be on gathering the product related failure information and especially the time and quality aspects of the field information. In time means fast enough to start the Product Improvement Process for changes/modifications at running products and improvements in next generations. The quality of the information means whether the field feedback facilitates a root causes analysis.
If the behaviour of products in interaction with the customer is well-analysed and communicated, recurrence of old problems in new products can be avoided. However, with respect to Fast Field Feedback attention will only be given to processing the information when it is relevant for a root causes analysis. Communication of the analysed root cause information throughout the organisation to make changes to running- and next generation products is part of the project scope, however, not how these activities are performed.

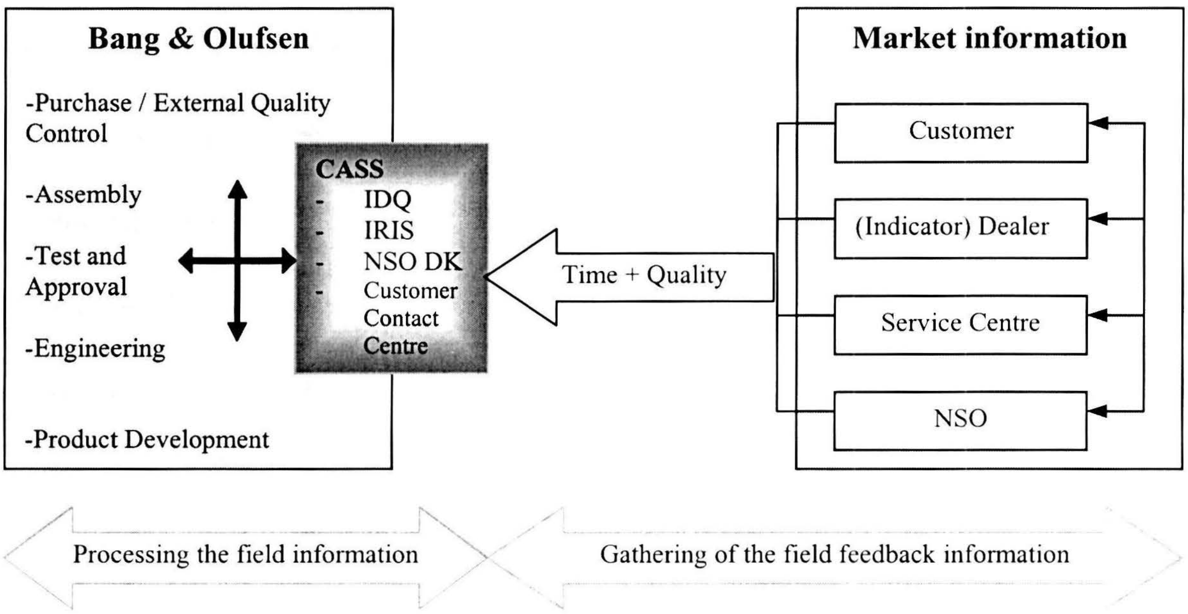


Fig. 12: CASS as the contact for field information

4.2 Time aspects

Getting field information is important in order to learn from problems and make necessary improvements. However, to facilitate fast anticipation of field problems the information has to be available quickly. This section describes the time aspects of the different sources of field information. The Customer Contact Centre (app. H) and the NSOs are not included in the analysis of fast field feedback and the suitability for performing an RCA; although it is partly product related information, their primary purpose is turnover and servicing the customer, not product quality improvement by providing field feedback.
The analysis is performed with respect to the target: To speed up the flow of field feedback when it is useful, meaning that it makes only sense to speed up the gathering of field information if it is also used in an earlier stage.
The analysis has to answer some questions regarding time aspects of the field feedback:
- Is the field feedback fast enough considering adequate and timely re-design on running products?
- Is it fast enough to make changes to new launched products to minimise the consequences (financial or product/production modification)?
- Is it fast enough to learn from and to anticipate quality and reliability risks from recurring in next product generations?

4.2.1 IRIS

This information is repair data in the form of IRIS codes (section 2.6.2).

<u>Facts and figures: IRIS and time</u>

- The goal of the repair data is 80% availability within 2 weeks and 100% within 4 weeks after the repair took place. In general, this is not achieved, however there is an improvement compared to last financial year (fig. 13).
- The lapse of time between the repair and the submitting of IRIS codes varies much according to countries (fig. 14). Different distribution structures and the availability of responsible persons are the most important causes of this time difference.

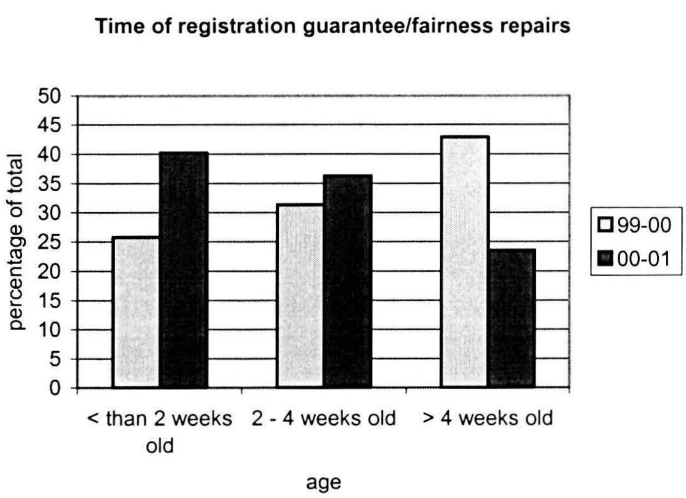


Fig. 13: Availability of IRIS data in weeks

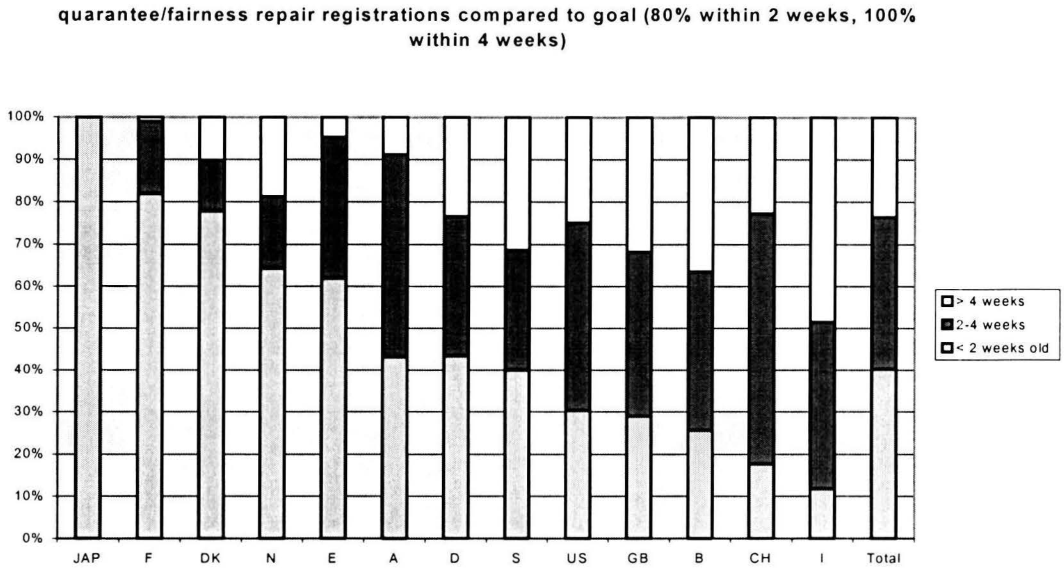


Fig 14: Availability of IRIS data by country in weeks

Graph 13 shows that the availability of IRIS repair data is displaying considerable improvement in the last financial year compared with the previous year. The goal set for the overall availability, however, is not reached. The different countries show major differences; some countries reach or approach the goal, where others not even come close. Some influencing factors on these major differences are known, but it is not clear what actions would be necessary to solve this problem.

<u>Analysis: IRIS and time</u>

- *IRIS, repair data*
- The availability of the IRIS data (fig. 13) has been 40% within 2 weeks and 76% within 4 weeks after the repair took place last year, and respectively 26% and 57% in the previous year (no data available from earlier years).
  This is an improvement, however, the goal of 80% within 2 weeks and 100% within 4 weeks is far from achieved. Figure 14 proves accomplishing this goal in some countries is possible. Actions to ensure that the goal is really pursued by the responsible persons in the different countries are necessary to avoid major negative deviations in the availability of the IRIS data.
- Looking at the detailed data (of each country per month) it is a reasonable goal with respect to the time aspect of FFF to have the major part of the information available within 2 weeks. This goal needs to be sustained and with an improvement of the present situation each year (a learning curve of 10 % a year like in the Call Rate of products from the market).
- The information is fast enough (when according to goal) for re-design of running products, however, the ideal situation would be that each product failure requiring change in product or process is known at Bang & Olufsen immediately. The flow of the IRIS data needs time after the repair to be processed in the different channels, such as the repairer, NSOs and the headquarters of Bang & Olufsen Struer.
  Every production day of products with a fault costs a considerable amount of money. If the product is already out of production when field failure information becomes available, a service solution (e.g. update with latest version) needs to be searched for.
- Product launches that are using a completely new technology or architecture demand a close follow-up at the markets where they are launched to anticipate not-foreseen quality and reliability risks. A product launch is normally first tried out on a specific market; the IRIS data are not fast to provide quantitative and qualitative information. Investigating

and reproducing the fault at the headquarters is a more valuable source of information in the case of not-anticipated problems.
So additional field feedback is necessary besides the repair data, e.g. IDQ information because this provides a fast symptom description of the product behaviour in the market.

Conclusion: IRIS and time
The availability of the IRIS repair data is not close to its goal, but an improvement compared to the previous year is achieved. The goal should be sustained with a proportional improvement each year, however, the huge deviation between different countries need to be decreased.

4.2.2 Indicator Dealer Quality

Facts and figures: IDQ and time

- The purpose of IDQ is that the Indicator Dealers send their cases on a daily basis, every time a customer has a disappointing quality experience. The primary purpose of the individual dealers, however, is their turnover, so a common way to send the cases to the IDQ consultants is in batches resulting in a delay of up to a week. The IDQ provides the service department with a fast feedback of customer cases within a week after the contact with the customer has been taken place.
- Seventeen dealers from Denmark, Australia, Singapore, United Kingdom and the United States of America provide the cases. Together they send an average number of 250 cases a month (fig. 15), with a negative deviation in the summer holidays and the Christmas rush, and a positive deviation directly after that.
- The different dealers show considerable differences in the number of cases they send, the reason seems to be that some dealers are just more conscientious in sending all quality related cases, and they recognize the importance of the IDQ program for Bang & Olufsen (and for themselves as dealers).

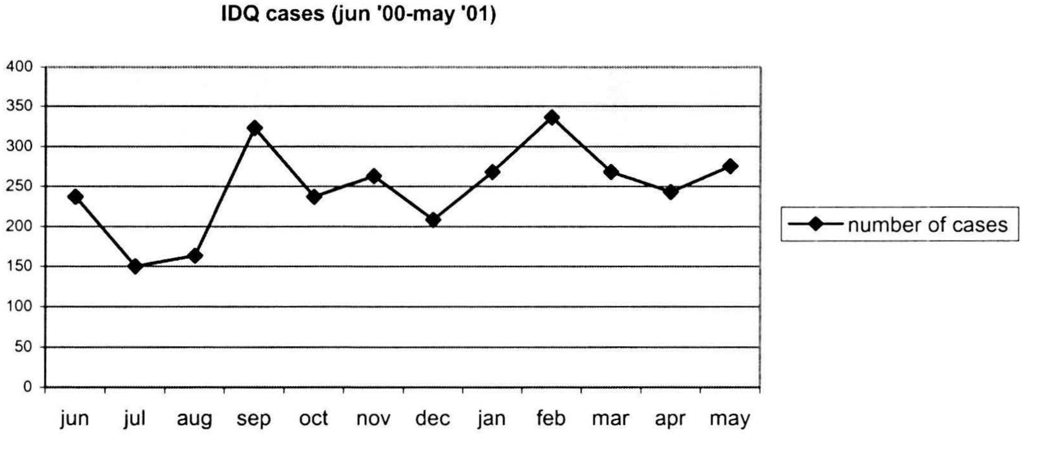


Fig. 15: Number of IDQ cases in the financial year 2000-2001

The graph shows a decline of cases in the busy periods of the year and more cases after these periods. It is obvious that (part of) the cases occurred already in these busy periods but were sent just after that. This is not a major problem when the dealers send the most important (time critical) cases immediately and the less time critical cases after the busy period, however, this is only on condition that the dealer is capable of judging how time critical the cases are.

Analysis: IDQ and time

- *Indicator Dealer Quality*

- The goal of the ID program is that the indicator dealers send the product related cases on a daily basis when they emerge. With respect to the time aspects of field information this is an ideal situation and the availability of the information is fast enough for each purpose of using the field data (re-design, service solutions or learning). What actions are executed depends on the moment of failure in the PCP and the stage of the product in the Product Life Cycle.
  The indicator dealer cases provide fast symptom descriptions in order to facilitate a fast anticipation of (new) problems in the market. It is used to inform Bang & Olufsen of a problem, and additional testing of the returned product is necessary to find the root cause.
- The common way of working shows that the cases are sent in a sort of batch, this can result in a delay up till a week. If the delay is not getting longer this is a minor problem issue, also because the dealers are pretty capable of judging how urgent problems are and they send these time-critical cases immediately.

Conclusion: IDQ and time

The Indicator Dealer Quality information is fast, however, the information is not complete so additional field information or testing is necessary with respect to new problems. The gathering of the additional information can cause more valuable time (for example getting the product in Struer and testing it can take a considerable amount of time).

4.2.3 Conclusion

The product-related field information that Bang & Olufsen, and particularly CASS, receives is available within a satisfactory time period. Only the negative deviation compared to the average availability of the field information requires attention. The more important issue, however, is whether the information is or can be used for a root cause analysis. This matter will be discussed in the next section.

4.3. Root Cause Analysis

Root causes analysis (RCA) is necessary to discover the primary reason for product failures in the market. Only when the departments involved in the PCP (product creation process) are informed about the root cause, problems in running products can be solved and avoided in future product generations.
This section gives the present situation of the field feedback and whether the information is used for a root cause analysis. The analysis of the field information is performed with the aim of making the field feedback more suitable and used for a root cause analysis.
Root cause aspects that need to be considered are:

- Source of the field information; customer, dealer, workshop, NSO. Loss of information due to several information exchanges or by not collecting information that should have been collected.
- When the field information does not lead to the root cause, does it indicate the location of the failure? Primary (organisation) means the location of the cause within the primary processes. Secondary location means the position within the product.
- On which part of the product failures from the market is a root causes analysis performed? To reach MIR level 4, each individual failure from the field should be examined on the root cause of failure. This facilitates the possibility to anticipate product/reliability risks in running products and to eliminate the risks in future products.

4.3.1 Repair data, IRIS

<u>Facts and figures: IRIS and RCA</u>

- The repair coding gives a detailed description of the customer's complaint. The symptom area gives the product's malfunction as perceived by the customer and the diagnosis area is intended for the technician to describe where the defect was located, and the actions that were taken to repair the product.
  When the product is repaired in the customer's home and the replaced module is going to Module Repair in Struer the IRIS codes are not used, the symptom codes providing only a rough indication of the problem and the diagnosis codes giving the specific information that the module has been replaced (so the secondary location (position) of the product failure manifests itself already in the module that need to be repaired).
  When the product is not repaired at the customer's but Product Repair the symptom and condition codes provide the customer's experience and the location of the failure within the product. However, there has been a loss of information, namely the customer set-up, which can influence product behaviour.
- The NSO, the service consultant and the TPMs filter the data; the invalid data for calculating the Call Rate and TOP lists are deleted in this way. The Call Rate, however, only has statistical and budgetary purposes, where as the TOP lists also provide priorities for improvement issues. The Call Rate and TOP lists do not have any value for a root cause analysis.
- The repair data of Bang & Olufsen consist of guarantee and fairness repairs (fig. 16). The guarantee repairs provide Bang & Olufsen with information about the first 2 years of the products in customer use (with some exceptions in specific countries). The fairness repairs also provide information about the products in a later stage of the Product Life Cycle. This is important because organisations are responsible for their products in the whole Product Life Cycle, including the wear-out phase. Nowadays the only information about the wear-out phase is from the demand of spare parts.
- Dealers are obliged to fill in the IRIS coding in order to get the claim approved. So even in cases where the complete reason and circumstances of the complaint are not known, some IRIS codes will be filled in. And this has repercussions on the validity/reliability of the information and accordingly to the value of the Root Cause Analysis.

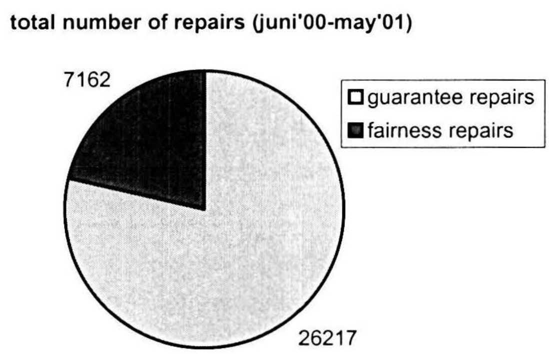


Fig. 16: Segmentation of guarantee and fairness repairs in last financial year

Analysis: IRIS and RCA

- The modules get an account number by entering Module Repair and the original IRIS codes are not linked to the module so the use of IRIS codes for performing an RCA is impossible. The possibility to use the IRIS repair data in Module Repair for a RCA is limited anyway because (1) the information of the customer set-up and (2) the interaction of the module within the original product have already been lost. And in addition (3) the location of failure is not necessarily the location of the root cause; meaning that when a module or component failed it can be caused by circumstances outside the particular module or component.
- Product behaviour is also influenced by the customer's set-up, however, this information is lost. And in addition the product failures that are submitted to Product Repair could not be repaired in the customer's home, so the information is not on root cause level. Although the repair department uses the IRIS codes to locate the failure, IRIS is not structurally used for a Root Causes Analysis (and finding all the dominant failures).
- The IRIS (guarantee and fairness) repairs are used for calculating the Call Rate; this is only for statistical and financial purposes and is of no value to RCA. The Call Rate is defined as the percentage of product failures (repairs) during the warrantee period at the market. The Call Rate shows the "learning curve" of running products compared to the goal of 10 % a year (and this information is available after a year). The accepted IRIS repairs (total minus invalid) are used for calculating the TOP10 lists of most frequent failures, this facilitates the choice of which repair categories need attention for improvement but it does not provide information for RCA.

Conclusion: IRIS and RCA

The IRIS repair data is specifically used for statistical and financial purposes like the Call Rate and TOP lists, and not for providing suitable information for a root cause analysis. The IRIS data is used in Product Repair to locate failures, but not structurally for a root cause analysis. If the IRIS codes filled in conform to the customer's experience (symptom area) and to the repair actions (diagnosis area), the failure can be located and the Root Cause Analysis can be facilitated.

4.3.2 Indicator Dealer Quality

Facts and figures: IDQ and RCA

- The feedback describes the customer experience about product-related subjects. The information is not technical repair feedback, but rather 'soft' complaints. It facilitates early symptom recognition for Bang & Olufsen, but the information is not useful for a root cause analysis. The information, however, could indicate a serious problem in the field and the failed product or module can be send to the headquarters for reproducing the fault and to perform a root cause analysis.
- The number of cases is quite small (average of 250 cases a month)(fig. 15) because only a limited number of Indicator Dealers participate in the program. A disadvantage therefore is that IDQ does not provide proper indication of how great the impact is in the market (on which market, how many products, which actions need to be undertaken etc.). A second disadvantage of the limited number of dealers is the possibility of missing important problems. Additional information from the market and/or internally via testing is needed to find the root cause of failure and the impact in the market. Only then well-founded re-design on running products or recently launched products is possible.

Analysis: IDQ and RCA

- *IDQ*
- The IDQ information is product related and provides early warning of failure symptoms. This is useful, because if Bang & Olufsen is informed about a new failure symptom that is suspected to be serious, they get the product to the Bang & Olufsen headquarters for testing and analysing for a root cause.
- Part of the information is useful for location analysis. Primary location stating which organisational part in the business processes is responsible for the failure. And the secondary location stating the position of the fault within the product. The IDQ information indicates the direction to start an RCA, but testing the returned product to reproduce the fault is necessary to find the root cause of failure.
- The information is not structurally used for RCA because it is not suitable for it. The major part of the product information is not complete; when the serial number is not provided, the production date is not known and as a result the used components, hard- and software versions are not known. This seriously complicates a detailed root cause analysis. Some kind of incentive for the Indicator Dealers to provide all relevant information could partially solve the problem of incomplete information.
- The feedback is product-related information about special focus areas, customer complaints and customer disappointments. It is possible (but not common practice) that Bang & Olufsen Struer requests for information about special areas of interest; for example recently launched products or issues where problems are expected. The possibility to ask for special areas of interest and clarifying questions facilitates an RCA. Customer behaviour and product usage can provide the necessary information to clarify the cause of failure. Product usage and customer behaviour can be measured by a blackbox that records the used functionalities and frequency of use. However, from a practical point of view it is too much effort.

Conclusion: IDQ and RCA

The Indicator Dealer Quality information cannot be directly used for an RCA because feedback is partly subjective instead of objective feedback, which means that a considerable part is rather 'soft' complaints instead of technical repair feedback.
However, the information is helpful in indicating (new) problems and for facilitating a first investigation of a potential problem.

4.3.3 Conclusion

The field information has some potential that is useful in performing a root cause analysis, however, this potential is hardly ever utilised. The presently performed RCAs use limited field information, only for categorising and deciding which product problems need to be analysed. The IDQ provides such symptom failure information.
In general the field information is not detailed (only symptom description), valid (IRIS codes filled in that are not right) or complete (missing technical- or customer specific information, such as serial number or customers' set-up) enough for a root cause analysis. The field information has to be improved in quantity as well as in quality to facilitate an RCA. And important is that information about field failures is a combination of symptom related information, repair actions and customer use/environment. Because the potential for improving the existing field information is limited, the focus is at finding additional ways of fast field feedback suitable for performing an RCA.

4.4 Flow diagrams of RCA

A Root Cause Analysis is a structured investigation aiming to identify the true cause of a problem, and the actions necessary to eliminate it [5]. A Root Cause Analysis is a problem solving process, one such problem solving approach is the PDCA cycle (see § 3.4).
This section describes aspects relevant to an RCA and some flow diagrams that give a comprehension of how the RCA is performed or should be performed at Bang & Olufsen.

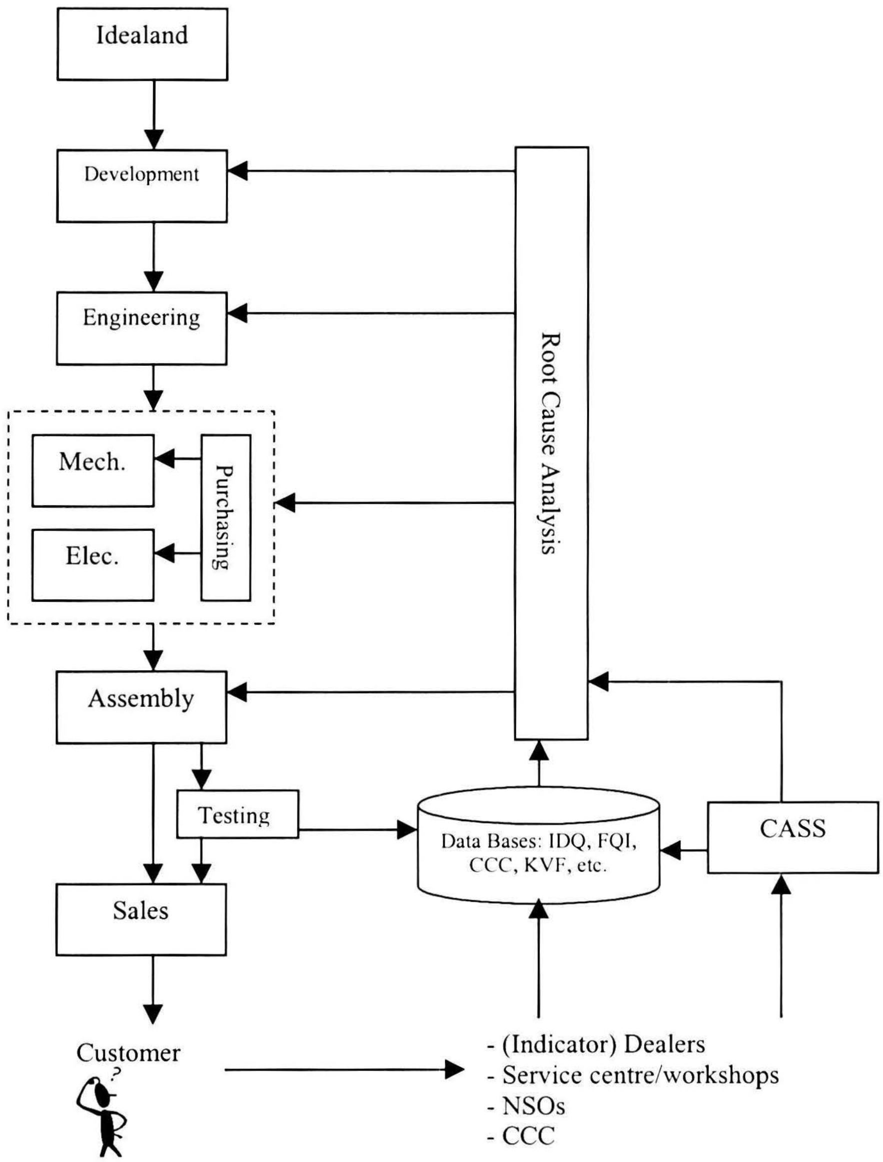


Fig. 17: Primary production process and the position of the RCA.

- Incorporating learning cycles: Testing and field information should be fed back to production and product development. And quality/reliability information from production to product development. This is done by analysing and documenting the information and performing a root cause analysis of the problems.
- These reactive learning cycles are formally in use (§3.5) but not fully implemented in the primary processes. Figure 17 shows that the reactive learning cycle (of quality improvement) should be in place by documenting and performing an RCA of the test –

and field information and feeding back the results of the RCA to the relevant parts of the Product Creation Process (PCP).

- The Root Cause Analysis of failures from the field and testing of finished products should be done by an RCA team with representatives of departments in the PCP (Product Development, Engineering, Purchasing/EQC, Component Production, Assembly, Test and Approval and CASS). In order to prevent an overload of the group it is recommendable to form a smaller group that has sufficient knowledge of all parts of the Product Creation Process. A group similar to the CD/DVD Driftgruppe (app. I) is very suitable to perform an RCA and to initiate the necessary Re-design changes. However, the CD/DVD Driftgruppe only handles products that incorporate CD or DVD.
  If a group similar to the CD/DVD Driftgruppe is responsible for the RCA, it should be possible for it to outsource the testing activities to a laboratory or testing department.

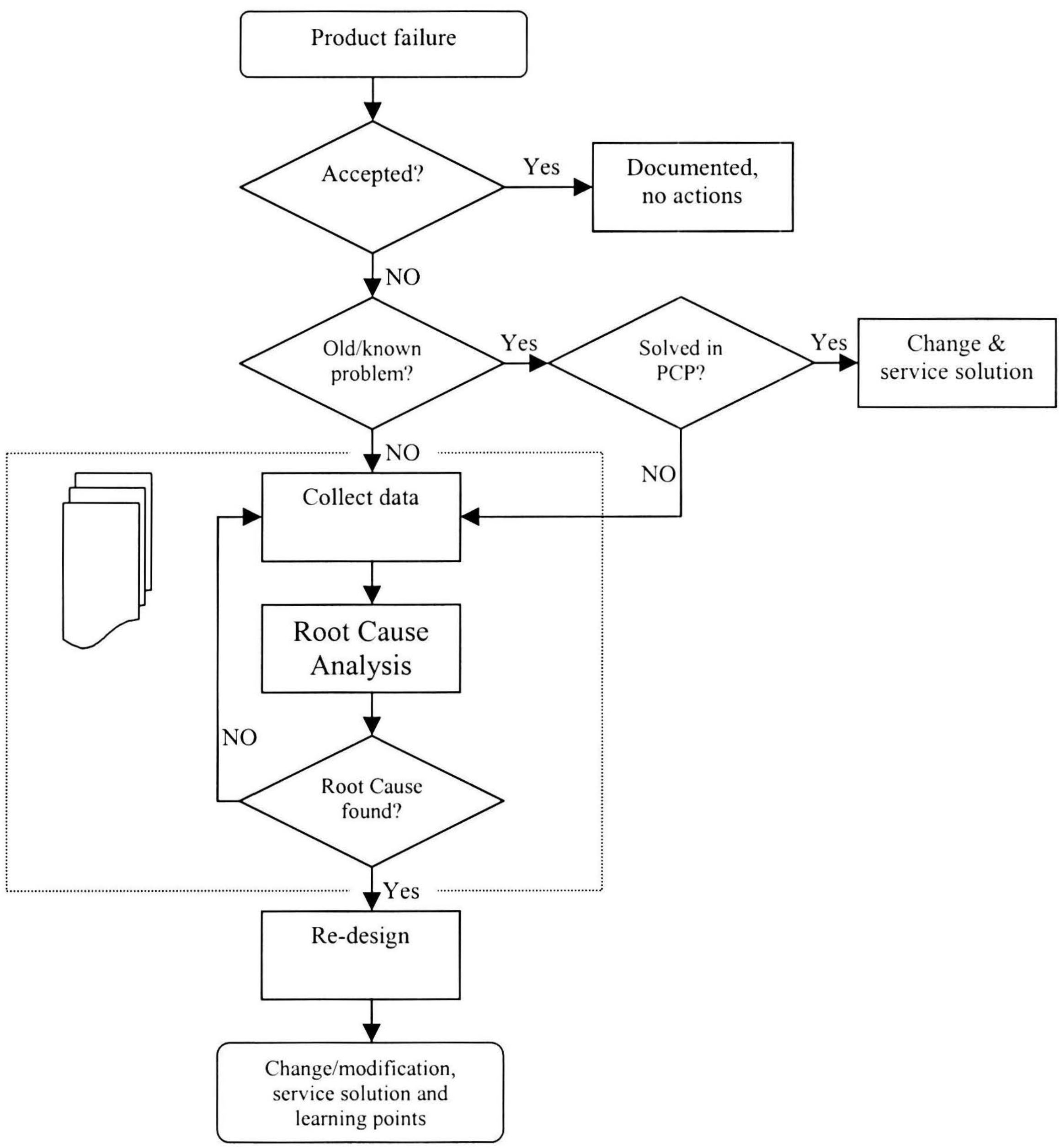


Fig. 18: From product failure to re-design changes/modifications and a service solution

The present situation
Product failures from the field coming into CASS are categorised according to whether they are incidental problems (that will be documented but no actions necessary) or high impact failures requiring change in the Product Creation Process (and a service solution for products already in use at the market).
A Root Cause Analysis is made on the 'high impact' failures and after the root cause has been found re-design activities are started to solve the problem. This results in a change/modification to the product and/or the production process, and a service solution (update with latest module, hardware or software version) for the products already in use in the market. At Bang & Olufsen the information regarding re-design activities is not always structurally documented and stored in order to prevent similar problems from recurring. However, the CD playability problem (app. G) resulted in adjustment of the supplier's CD mechanism to make it more robust for different CD specifications. Such problems will not recur in next/new product generations.

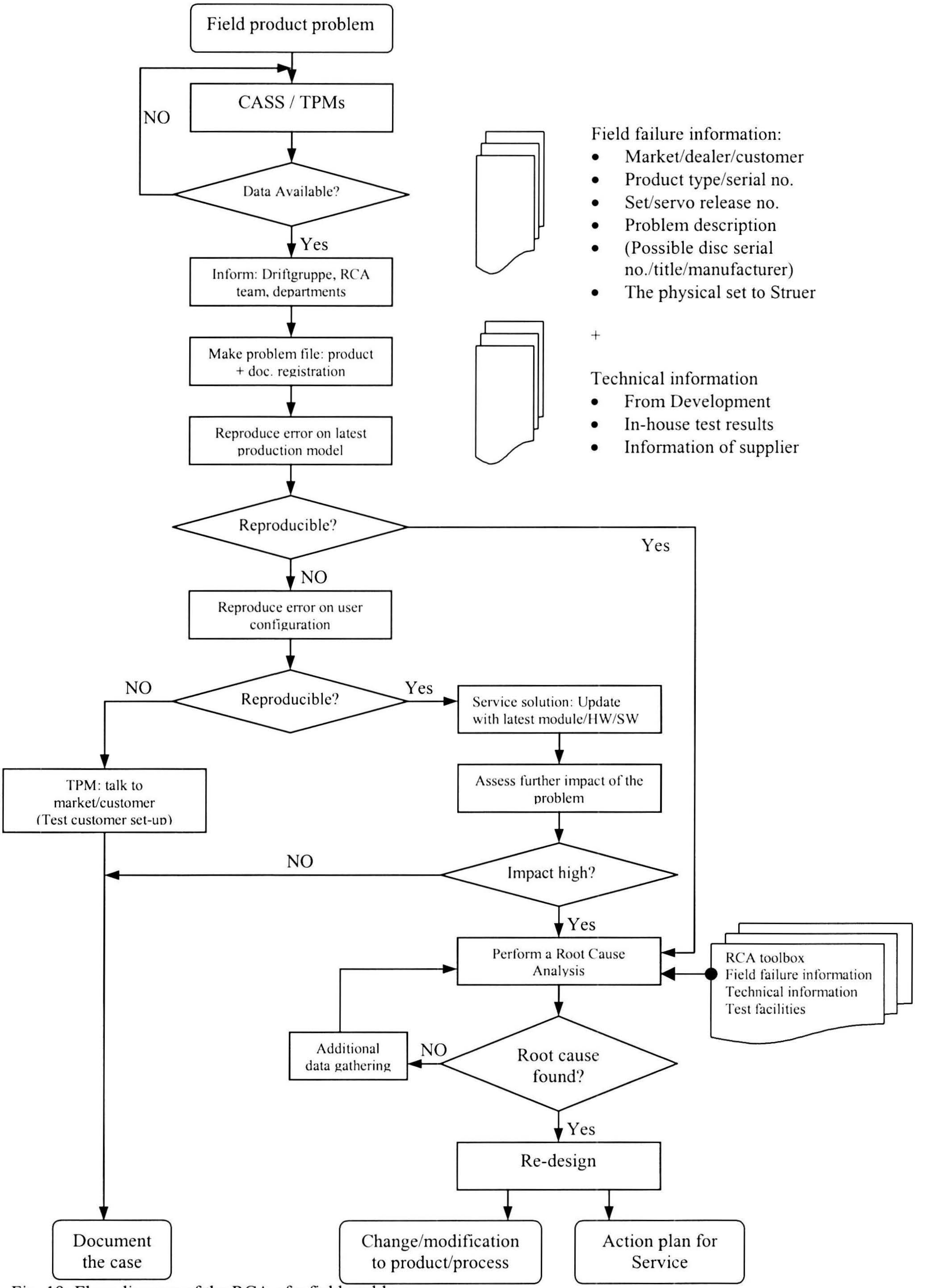


Fig. 19: Flow diagram of the RCA of a field problem

Future situation

The more structured way of performing an RCA in comparison with the ad-hoc based way the RCA is performed at present. CASS and especially the Technical Product Manager who has the product in his portfolio are responsible to provide the complete information from the field before the product fault is communicated further to the involved departments. The reason for this is not to disturb other parts in the organisation with minor problems and complaints. With respect to product related failure information the *traceability* is important. To achieve this the serial number of the product that failed should be part of the field feedback. Bang & Olufsen on its turn has to be able to lead the serial number back to all components, modules, hard- and software used in the specific product, this detailed on the level of which type and version. The traceability is important in order to initiate actions only for the relevant product range.

The persons who are informed: the CD/DVD driftgruppe (in case of CD/DVD related problems), the RCA team (persons who will execute the tests and the RCA) and the departments that will be involved in the re-design. The field information needs to be elaborated with technical information to make an RCA possible.

When the problem cannot be reproduced in the latest product models and on the user configuration, the cause will probably be the customer's set-up. If the fault can be reproduced at the user configuration a service solution with an update of the latest module/HW/SW is necessary. If the problem could be reproduced in the latest production models a root cause analysis is needed.

If the problem could not be reproduced on the latest production models but only at the user configuration, the service solution is an update with the latest version. When the service solution does not solve all (related) problems, further impact is assessed and an RCA is also performed if the impact is still high.

The input for the RCA is the field failure and technical information, the RCA toolbox (tools, methods and techniques), and the availability of test facilities where relevant parameters and functions can be calculated. The output is a root cause, which is used for initiating the re-design activities.

Conclusions

- Central testing facilities for performing an RCA on products returned from the market with a failure. An RCA team with technical (development) knowledge and from several departments involved in the Product Creation Process. The decentralised testing activities at Development, CASS, EQC and Assembly need to be centralised in order to improve the effectiveness of the several testing and RCA efforts.
- In order to fully utilise Root Cause Analysis, it must become part of a larger problem-solving effort. This means 'part of a conscious attitude embracing a relentless pursuit of improvements at every level and in every department or business process of the organisation' [5]. This approach requires a top-down attitude. Bang & Olufsen has the value 'to excel in every aspect of quality'; this needs to be communicated to all departments. CASS translates the goal for product quality as 'a fast, factual market feedback to the internal learning loops in Bang & Olufsen ensuring relevant corrective actions'.

  And for all departments within Bang & Olufsen the learning loops between departments are required for executing pro-active actions. For instance field information gathered at CASS can lead to the cause of failure by performing an RCA. Product Development uses this information for re-design of the running products, but also for preventing similar quality risks from recurring in future products.

4.5 Summary

This chapter has described the product related field information that is gathered within the after sales service department. At first some facts and figures of the present situation are discussed and in the analysis the field information is judged on the time and root cause aspects. The flow diagrams regarding the RCA of product problems from the field are also described.

IRIS repair data show potential for qualitative field feedback to facilitate RCAs. However, only when the information is valid, complete and embedded in the analysis process. The Call Rate, calculated from the IRIS data, is a tool to measure product performance. However, it is far from fast enough and therefore only a general indicator of product behaviour in the field. IDQ data is much faster, however, it is mostly subjective information and only partly symptom related failure information. Therefore IDQ information is used especially as warning signal for potential product problems in the field.

The next chapter will propose improvement alternatives to eliminate some problem issues that were concluded from the analysis of the present situation and that are consistent with the goal of the project.

5. Proposal for a new structure

This chapter describes a few alternatives that can improve specific quality and reliability related issues in the primary processes of Bang & Olufsen. The improvement points are stated and improvement alternatives are presented that can solve (part of) the problems. The alternatives are judged on their added value for fast feedback and whether the information is suitable for performing root cause analyses.

5.1 Introduction

With respect to the objective of the project, the improvement alternatives or proposal for a new structure should be able to; (1) speed up the flow of field information, (2) make the field feedback more used and more suitable for performing a root cause analysis (with one of the results a decrease of the number No Fault Found) and (3) make it possible to learn from past field failures and prevent them from recurring, this provides the opportunity to reach MIR levels 3 and 4.

1. In order to obtain the field feedback faster:
   - Gather the existing information in a more efficient and faster way; faster through the different channels or eliminating/skipping specific channels in the flow.
   - Gather quality and reliability related information representing the field behaviour of products in an earlier stage of the Product Creation Process, for example during production or via testing of (finished) products. However, this is more simulating product behaviour in the field than factual field feedback.
2. In order to obtain information suitable to perform root cause analyses a few issues are relevant:
   - Complete information; the product-related failure information needs to be extended. The specific product type, components and versions, including the failure symptoms should be known.
   - Combination of product related information with customer use and experience; the combination of information facilitates the RCA in a better way than the product related (failure) information alone.
3. In order to learn from past field failures a few aspects need to be considered:
   - The outcome of RCAs needs to be fed back to the relevant departments within the Product Creation Process and embedded in the quality improvement loop.
   - Prevent quality and reliability-related failures in previous products from recurring in next product generations.
   - Predict future product behaviour in order to take pro-active actions (service actions, re-design of product and/or process).

In the next section some improvement alternatives are proposed that will solve part of the above-mentioned issues.

5.2 Improvement alternatives

This section describes how the improvement alternatives are chosen, and each alternative is explained. The next section discusses and selects which alternative is the most advantageous.

5.2.1 Introduction

The results and deliverables of the Fast Field Feedback thesis project are translated into a number of improvement goals (see section 1.2):

- Decrease in the number of No Fault Found (NFF)
- Reaching Maturity Index on Reliability (MIR) level 3, opportunity for MIR 4
- Improvements to running products and/or production processes
- Learning from previous product problems
- Predicting future field behaviour
- Anticipating future product quality & reliability risks

The improvement goals prove to be heavily interdependent. To achieve these improvement goals some requirements have to be fulfilled. The four chosen improvement alternatives combined with different resources and fulfilled requirements facilitate achieving the goals. This is represented in figure 20.

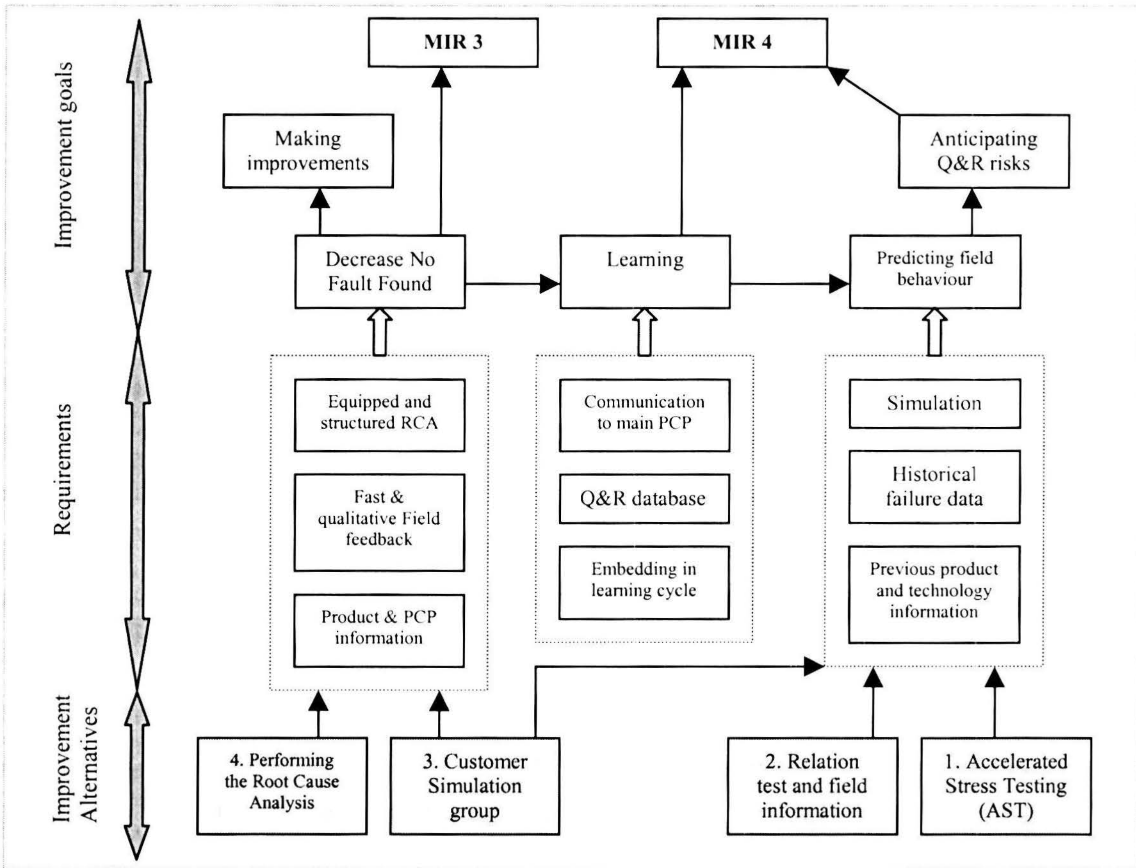


Fig. 20: Improvement alternatives

The four improvement alternatives are shortly explained by a few specific characteristics.

1) <u>Accelerated Stress Testing (AST)</u>
   a) Faster activation of product failures
   b) Predicting the failure mechanisms of products in the field

2) Relation between test and field information
    a) Determining a common denominator and the relation
    b) Predicting the field behaviour of products

3) Customer simulation group for 'pilot' products
    a) Identifying realistic customer behaviour
    b) Using feedback for fast improvements to product and/or process

4) Performing the Root Cause Analysis
    a) Re-designing actions based on RCA results
    b) Decreasing number of No Fault Found
    c) Pro-active learning

5.2.2. Explanation of the proposed alternatives

This section describes the specific improvement alternatives, such as a description of the before-mentioned issues in the previous section, main points and limitations. The improvement alternatives are explained regarding the issues of Fast Field Feedback, Root Cause Analysis and MIR levels.

1) Accelerated Stress Testing (AST)

AST strategies are especially used in time-driven development processes that require changing from a reactive approach to anticipating and preventing problems [8]. The pressure at the development process at Bang & Olufsen is not as high as in some other companies, because the Product Life Cycle and the development process at Bang & Olufsen is longer than the branch' average. AST is a classical solution [8] for the implementation of tests where product failures need to be activated faster and cheaper in a well-controlled environment at the early stage of the Product Development Process.
Currently used AST strategies are; HALT (highly accelerated life test), HASS (highly accelerated stress screen) [15], MEOST (Multiple Environment Over Stress Test) and RMEOST (Random Multiple Environment Over Stress Test) [8].
Malec [16] and Prakash [15] propose in order to achieve the goal of reducing manufacturing downtime during production ramp-up and to decrease early life failure rates, a three-pronged strategy. (1) Apply HALT to determine the robustness of design and manufacturing issues, (2) Use HASS to detect latent manufacturing defects and (3) develop the root cause analysis of field returns.

Main points
  a) Faster activation of product failures
      i) By controlled testing in the early stages of PCP.
      ii) Predicting the reliability of the product in the field already in the development phase.
  b) Predict the failure mechanisms of products in the field
      i) The subpopulations in the phases 1 and 2 (hidden 0-hour failures and early wear-out) of the roller coaster curve (see appendix J).
      ii) AST strategies especially predict the reliability behaviour of components, which is represented by the constant failure rate (phase 3).

Limitations of Accelerated Stress Testing
- Current AST strategies based on generic lists of failure mechanisms have only very limited relation to the actual failure rate curve of products [8]. These strategies especially take into account the constant failure rate. However, early failures

(subpopulations in the phases 1 and 2) in the four-phase roller coaster failure rate curve are at least as important for describing the quality and reliability behaviour of products in the field.

- The failure mechanisms tested in the AST strategies do not correspond with realistic product reliability performance in the field. This can be caused by activation of unrelated failure mechanisms, use of irrelevant stresses or wrong interpretation of the test results [8].
- AST strategies are only valuable if anticipated failure mechanisms that can be accelerated are present.

2) Relation between test and field information

A project with the goal of finding the relation between field behaviour of products and testing information of finished products already exists at Bang & Olufsen. Testing of finished products (KVF data)(see app. A) and field information (FQI repair data) should be (highly) related, however, the intermediate results do not show this. This indicates that tests have been performed either on parameters that do not correspond to realistic product field behaviour or no tests have been made on parameters that influence product behaviour in the market. Of course the possibility to test for climatic differences, customer behaviour and wear-out problems is limited. The correlation coefficient of the Avant television has been calculated to be 0.54 and 0.40 for Initial test/FQI and Burn-in/FQI [19] respectively. The target value is 0.8 so the possibility for pro-active customer service cannot be fully utilised yet. However, this project could be essential; if a high correlation can be determined, the test results can be used to predict the product behaviour in the field and pro-active after sales service can be executed to anticipate these quality and reliability risks.

Main points

a) Determine a mutual denominator and the relation
   i) Use IRIS repair codes: IRIS codes are suitable because the goal is to predict field behaviour (expected number of repairs) and the IRIS codes represent repair data. It is also very practical because IRIS codes are already collected by Bang & Olufsen.
   ii) Represent the test results also in IRIS coding. In order to compare two different information sources, the same mutual format is required for both the data. IRIS codes are a logical solution to do so.
   iii) Determine the relation between the IRIS codes from testing and the field.
b) Predict the field behaviour of products
   i) Judge whether the correlation is high enough to prove a relation between test and field data. Establishing a relation is hampered by the difficulty of testing for climatic differences, customer behaviour and wear-out problems.
   ii) A high correlation and prediction of the field behaviour of products would facilitate pro-active customer service, because test results reflect the product behaviour in the field.

Limitations of the mutual relation between field and testing data

- Difficult to measure the test and field information with a common denominator; at Bang & Olufsen both the repair data from the field and the test results can get IRIS codes in order to identify the mutual relation.
- The LTAP tests performed at Bang & Olufsen are 126-hour functional tests. These LTAP tests are 'test-to-requirements' and not like AST strategies 'test-to-failures' philosophies [27]. Wear-out product failures will occur in the field, but not in the short-lasting functional tests.
- Climatic differences, such as temperature, humidity, salty or smoky air, sandy wind, etcetera are difficult to simulate.

- Functions are tested, however, not in combination with customer use and customer set-up, and these interactions influence product behaviour.
- IRIS codes do not cover all product failures. In contrast to module and component faults, interaction related problems are not covered by IRIS codes.

3) Customer simulation group for 'trial' products

The functioning of finished products is tested in an attempt to determine the quality of the product. However, product quality and reliability is only defined in the field by the customer's perception of the product. According to this line of thought realistic customer behaviour should be simulated. In order to achieve this Bang & Olufsen has formed an employee group that uses some products for a period of time. In order to determine whether the current employee group achieves fast recognition of all possible product faults a similar group is needed to use as reference material. Bang & Olufsen only has to invest in and execute the Customer Simulation group once when the employee part shows satisfactoy results. When the results of the Customer Simulation group (with 50% employees) are compared with realistic product behaviour from the field later on. The decision can be made which combination of persons is suitable to gather fast and reliable "field" information to improve trial products before large-scale production starts.
Counter instruments are incorporated recording the use (function and frequency) of the product. It is doubtful whether or not an employee group reflects realistic customer behaviour, or that a different formation of the simulation group is needed. The most important objective, however, is obtaining fast market feedback of newly launched products in order to make possible re-design changes to product and/or process. The time gain will be from Production Start to the moment of Sales to the customer (fig. 21).

Main points

a) Identify realistic customer behaviour
   i) Incorporate blackbox, which records functionalities and the frequency of usage in each device, for example hours of use, number of times switching on/of, sequence of actions, etcetera. Determine at a meeting with involved experts which blackbox parameters, functionalities and frequency should and could be measured. The primary purpose of these user data is to facilitate RCAs of product faults and the secondary purpose is to investigate whether the Simulation group reflects realistic customer behaviour.
   ii) Compare customer simulation group (see Selection in section 6.2.2) with the existing employee group. Bang & Olufsen already executes a 'customer' test by providing particular products to employees for use and providing feedback. In these products counters are also incorporated. It is useful to determine the differences between the Customer Simulatation group and the employee group to determine whether these groups reflect realistic customer behaviour.
b) Use feedback for fast improvements to product and/or process
   i) Fast: the simulation group gets the products at the moment trial production starts (and before mass production). From this date onward field feedback can be gathered and this reduces the time span between production start and the sales to the final customer.
   ii) Suitability for performing an RCA; fast 'customer' information (symptom related complaints and product faults/failures) can be used to find root causes of (unknown) problems. The information from the blackbox can be useful for performing an RCA of the product failures.

Limitations of the customer simulation group

- Simulation group might have other expectations from the Bang & Olufsen products than real customers that pay for the products.

- Simulation group might not reflect realistic customer behaviour, so the situation cannot be predicted by extrapolating the results from the simulation group.
- The trial products are only allowed to have small differences with the mass production items, otherwise it will be impossible to generalise the results of the Customer Simulation group to product behaviour in the field.

4) Performing the Root Cause Analysis

Embedding a structured RCA, that is determined by formal procedures, in the quality improvement loop. In a way that reactive and pro-active actions are made possible regarding quality and reliability issues (with respect to MIR levels).
Figure 21 provides an indication of the place the RCA has within the PCP and the time gain of the Customer Simulation project is shown. The input, activities and output of the Root Cause Analysis are explained later.

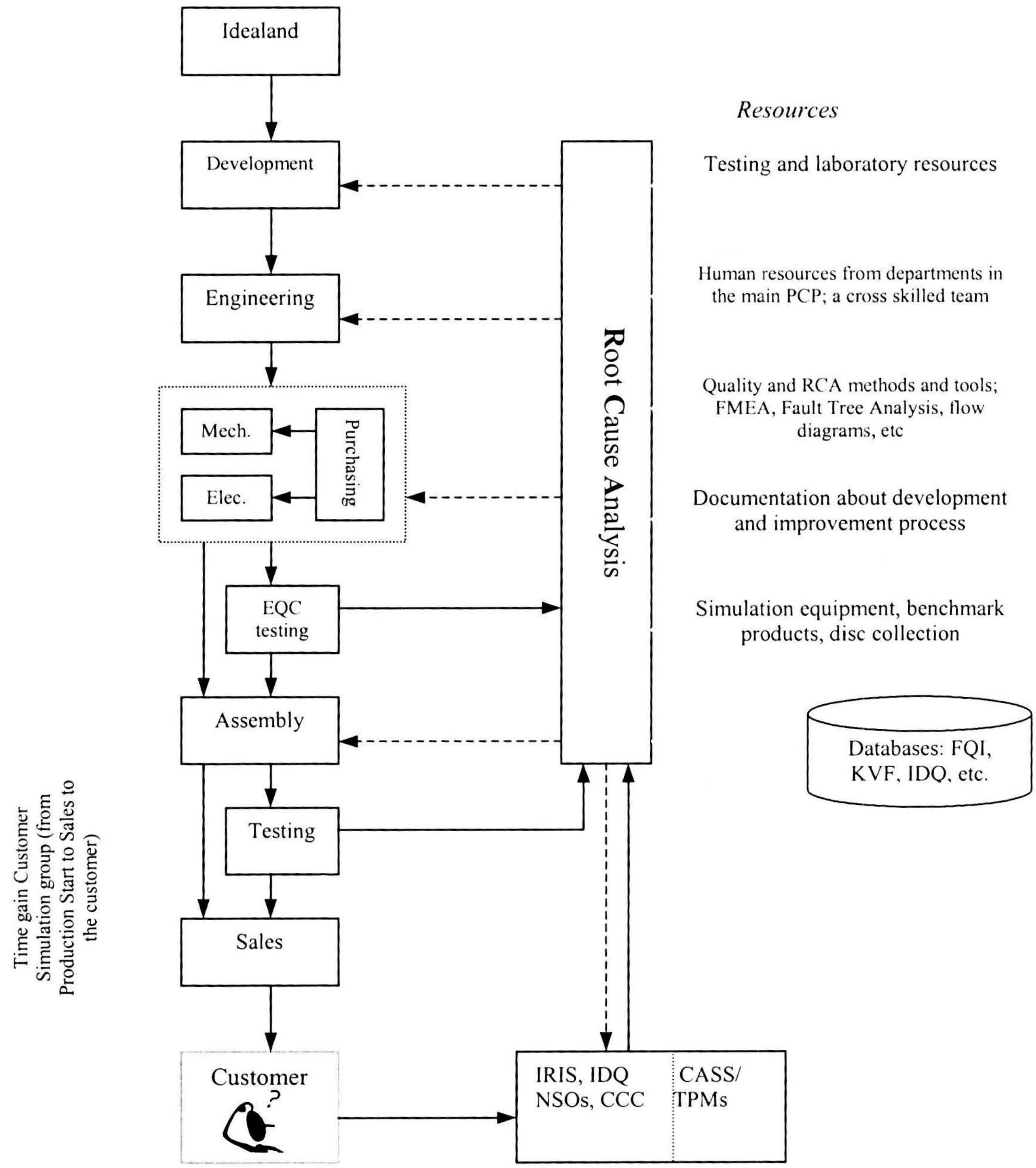


Fig 21: RCA within the PCP

Input to the RCA:
- Product problems from different parts in the PCP, especially testing and field failures.
- Different resources (see fig. 21) that facilitate performing a Root Cause Analysis.

Activities of the RCA:
- Performing an impact assessment of the problem by simulating and reproducing the fault in the user configuration and the latest product models. Assessing the impact of product failures can be done with the help of the "Market Quality Priority list" (see appendix E), which can be used to estimate and prioritise the parameters that are relevant for the impact of failures.
- Performing the Root Cause Analysis of the problem.
- Problem solving in order to indicate a solution direction.

Output of the RCA:
- The root cause of the problem that is investigated.
- Improvement proposal that informs the relevant departments in the PCP and indicates which actions could be initiated.
    - o Development (Engineering): re-design (re-engineering) a change/ modification in product and/or process.
    - o EQC/Purchasing: supplier change or quality improvement in cooperation with the supplier.
    - o Assembly: executing change in product and/or production process.
    - o CASS: service solution for products in the market.

Main points

a) Re-design actions based on RCA results
   i) Structuring the way RCAs of product failures are performed. This includes centralising the separate RCA efforts of product problems within the PCP (especially from External Quality Control, Assembly, testing and the field), equipping the RCA team with human, testing and laboratory resources, and providing the RCA team with as complete as possible information regarding the specific product problems.
   ii) The root cause of product failures is the prerequisite for making re-design activities for product and/or process possible. MIR level 3 is achieved when the business process is able to generate detailed information for all dominant failures on root cause level. And this can be translated into repairs/modifications in current products and anticipated risks for future products. A prerequisite of achieving the MIR level 3 is that the Root Cause Analysis and the learning cycle are embedded in the main PCP.

b) Decrease of No Fault Found
   i) A more structured and centralised way of performing RCAs (including identification of root causes, failure mechanisms and stressors) can lead to a decrease in the percentage of No Fault Found.
   ii) The information from the above-mentioned improvement alternatives facilitates performing RCAs and therefore a decrease in the No Fault Found.

c) Pro-active learning
   i) An RCA facilitates the possibility to learn from past quality and reliability problems, and to anticipate these risks in next product generations.
   ii) Embedding the RCA in the business processes and anticipating quality and reliability risks in next product generations creates the opportunity to reach MIR level 4.

Limitations to performing Root Cause Analyses

- Current results of RCAs are for a major part No Fault Found, and when not all dominant root causes of failures are found, MIR level 3 cannot be achieved.

- The RCAs are not structured, centralised, and the needed information is not always present, combined with the increasing complexity of products it is difficult to find the root cause of product failures.
- RCAs are not embedded in the product quality improvement cycle which restricts organisational learning and the opportunity to reach MIR level 4.

5.2.3. Conclusion

The four improvement alternatives are explained, with an elaborated explanation of the Root Cause Analysis. Estimating the advantages and limitations of each improvement proposal determines the selection of the alternatives and this will be done in the next section.

5.3 Selection of improvement structure

In order to determine which improvement alternative offers the best opportunity for fast and suitable field feedback for performing RCAs, the limitations of each alternative have to be considered. Also the advantages of the alternatives are listed once more in a fishbone diagram (fig. 22) (app. F).

Improvement proposals are meant to solve some of the issues of the Fast Field Feedback project. Improvement criteria (see in the fishbone between brackets) are:
1) Predict and/or prevent product failures in the field
2) Speed of field information
3) Quality of information suitable for performing an RCA

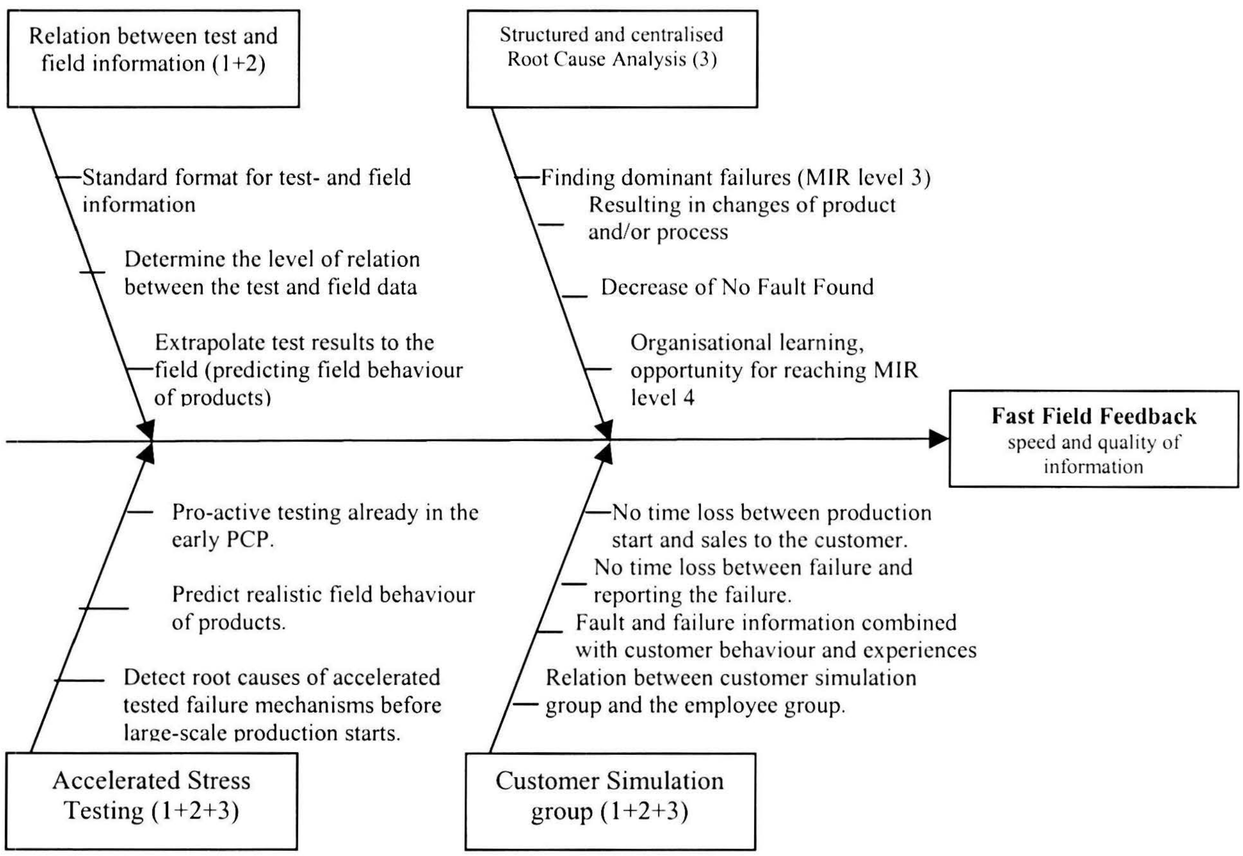


Fig. 22: Alternatives within the thesis project Fast Field Feedback.

Conclusion

Considering the advantages and limitations of the four improvement alternatives it will be most advantageous to focus on the "customer simulation group for trial products". "Accelerated Stress Testing" has little common ground with the topic Fast Field Feedback, because already in the development phase anticipated failure mechanisms (that can be accelerated) are tested. AST strategies cannot test completely for realistic product behaviour in the field, because for example customer specific use and product set-up cannot be simulated. However, the significance of AST is increasing due to the growing time pressure on the Product Creation Process and therefore the need for fast quality and reliability predictions.
The "relation between test and field information" provides the opportunity for pro-active customer service and the prediction of the product behaviour in the field. However, establishing the relation is hampered by the difficulty of testing for climatic, lifetime, and customer specific circumstances. The relation between testing and field information needs to be determined at Bang & Olufsen, because testing finished products should show similarities with the field. Otherwise testing is not based on realistic field behaviour of the products.
"Performing a Root Cause Analysis" is relevant with respect to the objective of the graduation project, however, performing an RCA depends heavily on the available information. The Customer Simulation group provides information directly from the participants, describing their experiences with the product, the possible fault and product usage (functionalities and frequency in the blackbox). This information is suitable for performing an RCA and with regard to the thesis project it also provides feedback much faster. The advantage of a mixed Customer Simulation group above an 'employee-only' group is that a more diverse formation of the group can be expected to reflect realistic customer behaviour in a better way. Accordingly also can be expected that the product will be used in different ways and show all possible product faults. Such as audio fans that use all possible functionalities heavily and persons without knowledge from the product that use the product in a way it is not designed for. Employees with prior knowledge of the product will not show such problems.

5.4 Summary

The analysis of the current situation at Bang & Olufsen in chapter 4 has provided the background information whereupon the improvement alternatives in this chapter are based. From the four alternatives the Customer Simulation group has been selected because the opportunity to improve shows best promise regarding the objective of the project Fast Field Feedback. The next chapter describes the roadmap for proceeding research and the implementation plan of the selected improvement alternative.

6 Implementation plan

In order to optimally benefit from the collected know-how and to reach MIR level 3 and ultimately MIR level 4, the improvement proposal should be implemented and the roadmap elaborated.

6.1 Introduction

This chapter first describes a general approach of how to tackle improvement projects related to the speed and suitability of feedback for performing RCAs. The way field feedback is processed and used for Root Cause Analysis in order to make re-design activities for product and/or process. And embedding the knowledge obtained from the field in the main PCP for personal and organisational learning. The MIR (Maturity Index on Reliability) levels have a central place in the improvement efforts of the recommended roadmap.
The Customer Simulation project focuses on obtaining quality and reliability related feedback, suitable for performing root cause analyses of product faults. And accordingly making re-design changes of product and/or process before large-scale production starts.
The implementation plan describes the way the Customer Simulation project should be executed. At first the goal is stated, then the effect on the speed of feedback information, and the results in connection with product quality. Finally the different activities, which have to be executed, are described in more detail.

6.2 Recommended roadmap

The recommended roadmap for Bang & Olufsen consists of the implementation and evalutation of the Customer Simulation group. Afterwards the improvement projects accelerated stress testing, relation between testing and field information, and structuring the root cause analysis have to be elaborated. This section also describes issues that are relevant with regard to the topics Fast Field Feedback and the Maturity Index on Reliability.

6.2.1 Topic of research

The relevant issues that have to be considered in improvement projects and the Maturity Index on Reliability are:

1) <u>Structure of obtaining the field feedback information</u>
   - Faster through existing channels
   - Besides existing field information gathering of additional field feedback
   - Quality of information suitable for performing Root Cause Analyses

The question "*What is needed?*" is important with respect to obtaining field information. Because the information has to be suitable for performing root cause analyses and it has to be available fast to minimise the consequences.

2) <u>Performing the Root Cause Analysis</u>
   - Identifying the root causes, failure mechanisms and stressors of quality and reliability problems. Not accepting No Fault Found as outcome of an RCA.
   - Formal structure for central RCA efforts and clear responsibilities of persons and departments
   - Incorporate the RCA of field feedback in the learning cycles

"*Is the field information suitable and used for performing RCAs?*" is the central question of this improvement issue. Root cause analyses are only successfully performed when relevant information is available and that is the purpose of the above-mentioned first improvement issue.

3) Elaborate the learning cycles:
   - More pro-active instead of reactive
   - More long-term instead of short-term
   - Embed the learning cycles in the main PCP
   - Facilitate organisational and personal learning

"Is the field information and the actions following the result of RCAs communicated to and secured within the main PCP?" The learning cycles are requirements for the ultimate goal of reaching MIR level 4. It is not enough to have formal learning cycles, it is also important to have the learning cycles embedded and used in the primary processes and the organisation. Four aspects that need consideration are given with regard to closed learning cycles. The opportunity to improve is challenging because learning cycles are heavily interdependent with departments and phases of the main Product Creation Process.

Conclusion

Focus of this graduation project is especially on (1) gathering fast and useful field information that can be used to (2) perform the root cause analysis. The purpose of the selected improvement alternative "customer simulation group" is to gather realistic field behaviour of products that will be launched in the immediate future. The simulation group will provide Bang & Olufsen with fast feedback about product faults, which can be used for root cause analysis and result in product and/or process changes before market introduction.

The above-mentioned improvement issues have a sequential character. At first the field information that is needed has to be gathered and structured. Then the information can be used to perform RCAs and at last the information and actions resulting from the root cause analyses need to be secured within the Product Creation Process of Bang & Olufsen to prevent past quality and reliability problems from recurring.
The gradual improvement of achieving a higher MIR level has a similar sequential character to the three above-mentioned improvement issues.

6.2.2 Approach for achieving MIR level 4

Although the availability of field information at Bang & Olufsen is sufficient (MIR level 1) and the failures can be allocated to the business processes (MIR level 2), the field information cannot be used to find the root causes of all dominant product failures. Implementing the Customer Simulation group will provide information that facilitates RCAs of quality and reliability related problems of the specific product. However, reaching MIR level 3 requires (field) information that will result in all dominant failure mechanisms for all products. Additional research is needed to provide Root Cause Analysis with the required (field) information.

Secure Maturity Index on Reliability level 2
Method:

- Data collection

Choose a specific mature product that has been on the market for some years as carrier for the assessment and obtain all relevant information that has been gathered on this product (the knowledge base). The data include information from the entire main PCP, from design to finished product and from subsupplier to final customer.

- Determine and eliminate constraints

Analyse the present situation and determine which information is missing and which constraints are obstructing the location of failures.
Find the potential solution methods for eliminating the constraints and reaching MIR level 2.

Achieve MIR level 3 and create opportunity for reaching MIR level 4
Method:
Incorporate/embed the Root Cause Analysis of returned products from the field and final testing in the Product Creation Process and make sure that the information and communication structure is deployed in the main PCP. The purpose of a structured way to peform the RCA and the deployment of the information into the main PCP are to facilitate finding the root cause (decrease of No Fault Found) and making the necessary follow-up actions.
Activities:

- Set-up of a laboratory team

Setting-up a workgroup that performs the Root Cause Analysis of returned product failures from the market and product problems from the main PCP. The CD/DVD driftgruppe (app. I) can be used as a platform group to obtain which information is needed, how the analysis of problems is handled, and in which way actions are initiated.

- Choose a mature product (or group of products)

Gather all the relevant (design, production, testing and field) information and record how problems with this product have been handled and solved in the past.

- Categorise the product problems

Categorise first the faults, like in the 'Q3 market quality matrix' (app. E), or the division in (A) fatal fault, (B) serious fault, (C) moderate fault and (D) minor fault (the CD/DVD driftgruppe categorisation). Focus the RCA and problem solving on the fault with the highest total priority score, or first the A faults, then B, C and D faults.

- Categorise the found root causes

There are different categorisation possibilities:

1. Design, Component and Process.
2. Component, Customer Use, Integration, No Fault Found.
3. Primary location (organisation); Development, Production, Operations etc. And secondary location (position); Hardware, Software, etc.

When the business process is able to generate information about all dominant failures on root cause level and in addition a decrease in the number of No Fault Found is achieved, MIR level 3 is reached. This is also the starting point for achieving MIR level 4, because the lower level requirements have to be fulfilled first.

6.3 Implementation plan for the Customer Simulation group

This section describes the implementation plan of the Customer Simulation project. In chapter 5 it has been estimated to be the most advantageous alternative for fast field feedback. The goal, activities and explanation of steps of this improvement proposal are given.

6.3.1. Goal

The goal of the Customer Simulation group is twofold. Both goals are pursued, however, the primary goal is given preference to the secondary goal.

Primary goal: Obtain fast quality and reliability related failure information from the customer simulation group describing the experiences of the trial products, in order to make improvements to the product and/or process before large-scale production starts.

Secondary goal: Determine whether the Simulation or existing Employee group reflect realistic customer behaviour. When the results are satisfactory (primary goal is obtained) and the Customer Simulation group reflects realistic customer behaviour, the group has to be made common practice within Bang & Olufsen. Future field behaviour can be predicted only when the results are product independent.

Information is available faster because:

- The time elapsing from Production Start to the moment of Sale to the customer has been skipped. The time lapse is caused by stock of finished products at Bang & Olufsen waiting for shipment, transport to and stock at the dealer (dependent on the stock of a possible predecessor), and the sales to the customer.
- Shorter communication line; the normal procedure of obtaining field information is through the channel from customer to dealer, dealer to NSO, NSO to CASS, CASS internally to the responsible persons/departments. The feedback loop of the Customer Simulation project is shortened by the direct contact of the Customer Simulation participants with the contact agency. This is advantageous to the speed and completeness of the information.

Results for product quality (and reliability):

- To discover not anticipated quality risks of the new trial product, due to faults in product architecture, design, software or applied technology. Accordingly, improvements to the product can be developed and executed before the product launch will take place.
- The products from trial production, which are distributed to the simulation group are required to have the same specifications as the products that will be distributed to the market, otherwise prevention of symptoms that will not occur at the market is pursued.
- The hidden 0-hour failures and early wear-out problems will be discovered and, where possible, prevented from recurring before the product launch. Random failures are difficult to anticipate and the systematic wear-out failures will not occur in the (short lasting) customer simulation project.

6.3.2. Activities

A number of activities have to be executed in order to complete the project successfully. The activities are divided according to order of time; before the start, during or after finishing the Customer Simulation project.

Before the start of the Customer Simulation project
1) Approval of management
2) Product Selection
3) Group/participants selection
4) Set-up of contact agency
5) Building the blackbox into the "simulation" products
6) Country selection and distributing
7) Formulating questionnaires

During
8) Reading out the blackbox and distributing the inquiries simultaneously
9) Processing the contacts with the agency at Bang & Olufsen
10) Re-designing changes to product and/or process

Afterwards
11) Processing the inquiries and blackbox data
12) Comparing the subgroups to find differences and mutual similarities.
13) Gathering realistic customer behaviour and comparing with the simulation group.

<u>Explanation of the activities</u>
The requirements, interpretation and points of interest are described to elaborate and detail each activity.

Before the start of the Customer Simulation project
1) Approval of management
    a) Determining the expected/calculated costs
        i) The (production) cost of the simulation products, possibly deducted with revenues from sales after project ending (at a lower price).
        ii) Labour costs for extra staff. Employees for the contact agency, reading out the blackbox and processing the data from the blackbox and the questionnaires.
        iii) Distribution costs of the products, from Bang & Olufsen to participants and back, and also travelling expenses for reading out the blackbox.
    b) Giving an estimate of the profit/gain
        i) The estimated gain of time between Production Start and Sale to the customer is 2 to 3 months. Whenever a fault occurs in the Simulation group that can be changed in running production before it reaches the market, a service solution or a distribution stop can be avoided.
        ii) The Customer Simulation group can discover product failures that will prevail in the field and that are not discovered by testing. If so, changes to product and/or process can be made before the product with the fault reaches the final customer. This saves a late service solution in the market and prevents the loss of goodwill and negative impact on brand image.
        iii) If it is determined that the Customer Simulation group reflects realistic customer behaviour, product behaviour in the field can be predicted by extrapolating the results of the Customer Simulation group. This saves a lot of time because the predictions can be made after the first trial products have been manufactured and distributed to a customer simulation group.
    c) In case the management is persuaded that the profit will exceed the costs, their approval will be the starting point for the project.

2) Product Selection
   a) An audio product has to be selected, because this group of products has an historical higher Call Rate than the average product at Bang & Olufsen [20].
   b) Requirements
      i) The project has to be initiated before Production Start, preferably in the final stage of development or trial production. The product has to be followed during the first months of use within the Simulation group until at least the moment when the product is distributed on a larger scale to the final customer.
      ii) A renewing concept (technology, software or hardware) should be incorporated in the product. It is of no use to pick a mature product whose behaviour in the market is known and where no quality and reliability risks can be expected.

3) Group/participants selection
   a) With respect to the primary goal of obtaining fast failure information a few issues need to be considered.
      i) Product faults have to be identified as fast as possible to minimise the consequences by performing re-design activities on product and/or process, this requires heavy users as participants.
      ii) All possible faults have to be identified; this requires a diversity of different persons in the simulation group. Technical persons (or audio fanatics) that can be expected to use all possible functionalities of the product, but also technically inexperienced persons who may use the product in ways for which it was not designed and/or tested.
   b) With respect to the secondary goal of reflecting realistic customer behaviour by the Simulation group different aspects of forming the group need consideration.
      i) The simulation group has to consist of a diversity of persons that reflect ordinary customer behaviour. This is not a difficult issue, however, a simulation group getting the product for free might have different expectations from customers who are paying for the product.
      ii) To establish a formation of the group which will reflect customer behaviour most accurately the group should consist of an employee part and a randomly chosen part with persons of different age, background, sex, occupation and living circumstances (how many persons in the household will use the product). This point is especially relevant for practical reasons. If the employee group reflects realistic customer behaviour on a satisfactory level, there is no need to form a special Customer Simulation group. However, it needs to be investigated anyhow to establish the fact whether a Simulation or an Employee group represents realistic customer behaviour.
      iii) The size of the group needs to be big enough to provide sufficient feedback of all possible failures and also to provide enough data in order to compare the different subgroups. However, in order to minimise the financial consequences the number of participants needs to be limited. A simulation group of 50 to 100 participants will probably fulfil both requirements, depending on what is realistically feasible.
   c) By forming the group the primary and secondary goals need to be taken into consideration, however, in case of conflict between the goals, the primary goal gets preference.
      i) Divide the group into two: one half consisting of employees and the other of for instance persons from universities or persons responding to an advert to participate in the Simulation project. Some selections criteria (as in point b ii) have to be used to choose these persons otherswise you possibly get a formation of the group that influences the results negatively. In this way a comparison between the different 'customer' groups can be made.
      ii) In order to get as fast as possible and as much as possible feedback, users who put stress on the product and who will use all existing functionalities have to be

selected. Students and employees familiar with the technology are suitable for this requirement.

iii) Divide the employee group into a technical and non-technical (administrative staff) part and divide the university group into students and senior staff members.

iv) The previous points result in a group of a fourth part students, a fourth part university staff members (administrative and technical), a fourth part technical Bang & Olufsen employees and a quarter administrative Bang & Olufsen employees.

These results have to be compared later on with realistic customer behaviour. In this way future customer behaviour can be predicted from a next simulation group. However, the product might have been improved in the meantime and certain failures will not occur anymore. The results of the Customer Simulation group can only be generalised if the results are not product dependent.

4) Set-up of contact agency

Internet based contact between the participants of the simulation group and Bang & Olufsen by e-mail and the possibility of elaborating the contacts on the telephone.

a) The OD (Optical Disc) Driftgruppe (App. I) (group responsible for all CD/DVD related problems) is a suitable working structure that has engineering knowledge to estimate whether the contacts made need follow-up (re-design) actions. A development employee should do the actual handling of the contacts, however, the OD Driftgruppe has to be kept informed about product faults in the customer simulation project.
b) The OD Driftgruppe has direct contact with Product Development and especially the link with development staff responsible for the specific product needs to be established.
c) The processing of the periodical reading of the counters can be outsourced, however, the results have to be fed back to the "customer simulation group" database that is used to store all the information relevant to the project and relevant to the contact agency.

5) Building the blackbox into the "simulation" products

The blackbox records the product usage, particularly used functionalities and the frequency of use in each device. Examples are hours of use, number of times switching on/of, sequence of actions etcetera. A meeting with experts is necessary to discuss which parameters could and should be measured by a blackbox. Different product use by the customer influences product behaviour and in addition the faults that occur. This information is essential to perform RCAs. The product (with blackbox) should be labelled with the personal information of the user in order to prevent losing user/product information.

6) Country selection and distribution

Take products from trial production and distribute them to the simulation group. In order to minimise (distribution) costs, simplify the communication, and ease of visiting the customer for reading out the blackbox, it is advisable to choose a Danish university and the employees from the Struer headquarters. A university is suitable because students can be expected to use all possible functionalities of the product heavily and senior staff members can be associated with the target group. Even more important is that a university is research minded. University will be cooperative because they take much interest in the results of research projects like the Customer Simulation group.

7) Formulating questionnaires

The questionnaires have to obtain the following information:

a) Missing information about the participants' patterns of use, which cannot be measured by the blackbox.

b) Personal characteristics of the subgroups influencing the way the participants use and perceive the product, called a customer profile.
c) Besides the feedback to the contact agency, the questionnaires have to indicate the participants' product quality experiences.

During the Customer Simulation project
8) Reading-out the blackbox and simultaneously distributing the questionnaires
In order to obtain additional feedback during the project the counter parameters of the blackbox are measured periodically (after 1, 2 and 4 months) and supplemented with the questionnaire. Especially the early failures (subpopulations) from the phases 1 and 2 of the roller coaster curve will be discovered, and these subpopulations probably will show themselves before the measurements of 1 and 2 months. The random failures can occur for the whole duration of the project and wear-out problems probably do not occur.
The time elapsed between Production Start and Sale to the customer will take approximately 2 to 3 months; so after 4 months from the start of the Simulation group the field feedback from the market will reach Bang & Olufsen via the existing channels and the project can end. However, the field feedback from the final customers has to be gathered to make comparison with the Customer Simulation group (university part and employees) possible.
Reading-out the blackbox and processing the questionnaires can be outsourced, and it is advisable to execute it centrally because visiting the participants is too costly.

9) Processing the cases with the contact agency
The CD/DVD Driftgruppe has to screen the contacts on not-known (high impact) faults/failures and to pass these cases on to the responsible development staff.

10) Re-designing changes to product and/or process
Failures/faults passed on by the contact agency have to be judged, by performing an RCA, whether re-design changes to product and/or process have to be initiated.

Afterwards
11) Processing the questionnaires and blackbox data
The questionnaires have to be made in digital format. This facilitates faster and easier distributing, collecting, filling-in and processing of the data. Also the blackbox data have to be imported in a spreadsheet to facilitate processing and visualising the data.

12) Comparing the subgroups to find differences and mutual similarities.
Especially the pattern of use of both groups are relevant and the faults and failures that occurred in both groups. Later on the data of these two groups have to be compared with realistic customer behaviour and the field failures to establish whether one or both these groups reflect realistic customer behaviour.
Within the university group the difference between students and senior staff members can be determined. However, no conclusion can be drawn on what really caused a possible difference, because that depends on several parameters; for instance age, education, background, living circumstances and product usage. However, these parameters can be used to select future "simulation" groups.
The difference between technical and non-technical (administrative) staff members in the employee group are especially interesting to determine if in-house knowledge of the product has substantial influence on customer use and product failure behaviour.

13) Gathering realistic customer behaviour and comparing with the simulation group
a) The time elapsed from Production Start to Sale to the customer has been estimated to be 2 to 3 months, so during the project the product launch will also take place. The results of the Customer Simulation project (and subgroups) have to be compared with realistic customer behaviour, so the product behaviour in the field has to be measured in a similar format to make comparison possible.

b) Comparing the results of the Customer Simulation group with realistic customer behaviour and determining whether it will be relevant to predict future product behaviour from the results of a simulation group. The purpose of the Customer Simulation group with partly university persons and partly Bang & Olufsen employees is to determine the ideal formation of the group. This includes the analysis to establish whether the current employee tests are suitable to execute 'customer simulation' tests. However, reference material is necessary to perform this analysis what resulted in the diverse subgroups. If not-anticipated field problems occur and the employee group did not show this, however, other subgroups recognised the fault. Then an employee-only group would not achieve the purpose of gathering fast and complete 'field' feedback for making improvements to the trial product. Resulting in a diverse formation of the simulation group to catch all possible product problems.

These 13 steps have to be executed before, during and after the Customer Simulation project. Some are more important than other, but all activities have to be executed.

6.4 Summary

The roadmap for further research should include the implementation of the improvement proposal of the Customer Simulation project and elaborating the other discussed alternatives. In addition to the Customer Simulation group the focus could be on performing the Root Cause Analysis (see section 5.2.2). Focus on performing the RCA is a logical step in succession to the Customer Simulation project because an RCA depends on the speed and quality of field feedback, which is the primary goal of the Customer Simulation project.

7 Conclusions and Recommendations

Besides the implementation plan of the improvement proposal and the roadmap for further research, conclusions can be drawn and some recommendations can be given.

7.1 Conclusions

Bang & Olufsen is with regard to the Maturity Index on Reliability mainly at level 2. The availability of field data within Bang & Olufsen is high and the relevant data analysis techniques are systematically applied in the business process (MIR level 1). In general the location of failures, organisational place in the Product Creation Process and position within the product, is well determined (MIR level 2). Root Cause Analyses are performed in a less structured and systematic way, only for 'high impact' quality and reliability related problems an RCA is performed to find a solution and make changes and/or modifications to current products. So the business process is not able to generate detailed information on all dominant failures on root cause level and therefore Bang & Olufsen has not reached MIR level 3 yet. The proposed Customer Simulation project provides the first impulse to fast field feedback information suitable for use in performing RCAs and therefore the opportunity to reach MIR level 3.

The primary goal of the service process is servicing the customer and it is only partially assessed on its contribution to improvement of product quality and reliability. Only the Indicator Dealer program and the tasks of the Technical Product Managers are an example of contribution to product quality and reliability improvement, respectively gathering field information and coordination of handling the field problems. However, the main goal of service is still to help the customer as fast as possible and in a satisfactory way. The challenge is to achieve the right balance between servicing the customer, and in addition to this the task of contributing to quality and reliability improvement by providing field feedback information.

The *objective* of the graduation project has been stated at the start as:

> To develop an approach to improve and implement a rapid feedback structure on product and process quality and reliability failures. A well-established and formal programme organisation has to be developed to allocate and identify the root causes of quality & reliability issues at both business and technical process level.

The four improvement alternatives have much ground in common with the objective of the thesis project, however, the chosen Customer Simulation group fits the objective best because, when implemented, it provides fast feedback. And when the simulation group proves to reflect realistic customer behaviour the feedback given by the simulation group is similar to field feedback. The information facilitates a Root Cause Analysis, however, currently performing RCAs is ad-hoc based. Opportunity for further research is to structure and centralise the performing of RCAs for product failures from the field, and also from final testing and production.

7.2 Recommendations

- *Evaluation improvement proposal*

When the implementation plan of the Customer Simulation project has been executed, the project needs to be evaluated on the added value to the primary and secondary goal it intended to achieve. Meaning that the results has to be judged on whether the feedback from the simulation group provided Bang & Olufsen with information helpful in finding root causes of problems, and whether changes in product and/or process are executed, which were indicated by the fast feedback of product faults by the simulation group.
When the first goal has been achieved and if the simulation group reflects realistic customer behaviour, a Customer Simulation group can simulate future product behaviour in the field. This is on condition that it will be valuable, meaning that new products are launched where not-anticipated quality and reliability risks can be expected. And accordingly these not-anticipated quality and reliability risks can be recognised in a next customer simulation group instead of later on in the market.

- *Improving the current field feedback flows*

The existing field information flow still has some potential for improvement regarding the speed and quality of field feedback. Therefore the Customer Simulation project has been proposed to provide additional fast field feedback, however, the Customer Simulation project is not a substitute for existing field information. Attention to the existing field information should be focused at:

- IDQ data is available fast, however, the information should be extended in order to fully utilise its potential. The number of Indicator Dealers could be enlarged to prevent missing important product faults. And the contacts need to be formalised in order to be as informative as possible, meaning that for example serial number and customer's set-up and experiences have to be included in the customer contacts.
- The availability target of the IRIS data should be pursued in every country to minimise the huge negative deviation from the target in some countries. The symptom and diagnosis area of the IRIS data is useful information, however, this is not yet utilised in the normal working routine. The information could be incorporated in the formal RCA structure to facilitate a decrease in the number of No Fault Found.

- *Elaborating the learning cycles*

The learning cycles have an important role in learning, meaning that outcomes of RCAs are documented, stored and shared within Bang & Olufsen in order to secure individual and organisational learning and preventing past problems from recurring.
Learning cycles and quality improvement loops result in a challenging opportunity to investigate because of the relations, interactions and interdepencies between phases and departments within the Product Creation Process.
Some points of interest are:

- What is missing in the existing (quality & reliability related) learning cycles (section 3.3):
  - Deployment within Product Creation Process
  - Quality of information (coverage, level of detail, suitability for RCA)
  - Communication to relevant parts in PCP
  - Knowledge management: the way information is documented, stored and shared within Bang & Olufsen
- The learning loops need to be changed from predominantly short-term reactive loops to more pro-active long-term control loops. The reactive short-term loops are especially problem solving loops within departments. The communication to earlier phases of the Product Creation Process is limited and therefore these phases are obstructed in performing pro-active actions to anticipate future quality and reliability risks.

- The learning loops have to be integrated in and communicated to the whole product creation process in order to facilitate pro-active learning and the possibility to predict quality and reliability aspects through learning about earlier experiences.

- *Test procedures*
- Test strategies are not based on field information and therefore test-based predictions do not match with realistic product behaviour in the field. New technologies and increasing complexity of products require a change of testing procedures in order to match field behaviour of products. An opportunity would be to develop more effective testing procedures and parameters.
- External quality parameters: CDs and DVDs for instance influence the quality of product functioning. Testing is not fully adjusted to the changing quality of discs. Up till now there has been no structure in gathering CDs and DVDs for testing finished products and this is a possibility for improvement. A procedure to gather discs in a structured way and to test the functioning of products with a broad range of different discs is desired. The structure should cover the answers of:
  - Discs from which market, title and manufacturer
  - How many discs
  - Update of discs in what time period (every x months buying new additional discs or replacing all present discs at once every x months)
  - Which person/department is responsible for buying the discs, deciding on the test parameters, setting up tests, performing the tests and giving feedback on test results to which persons.
  - A disc database; labelling the discs, documenting and storing all discs.

The 'playability problem' and the distribution stop to the USA possibly could have been avoided if products were already tested in Struer with the 'out-of-spec' CDs from the USA market.

- *Knowledge management*

Styling aspects are given priority to the quality and reliability aspects, which can cause problems later on in the PCP. Reliability prediction and management are limited to Product Development, only estimations are made of the influence specific product architectures and technologies might have on product quality and reliability. The storage of know-how is also limited in PD, re-design actions are not documented reducing organisational learning. And also individual learning because know-how is limited to the people involved in the re-design activities. This can be avoided by storage of this information in an organisation-shared database.

The recommendations can be summarised in three "to-do"activities:
1. Implement the customer simulation group for a product where not-anticipated quality and reliability risks can be expected. Evaluate whether the intended goal of the customer simulation group is obtained.
2. Use the feedback from the customer simulation group for performing the root cause analysis of field problems. Accordingly a decrease in the number of No Fault Found is pursued and this is the base for reaching MIR level 3.
3. Ensure the information from field failures and the results of RCAs are documented, stored and shared within Bang & Olufsen. To achieve MIR level 4, this information has to be incorporated in the learning cycles and embedded in the Product Creation Process.

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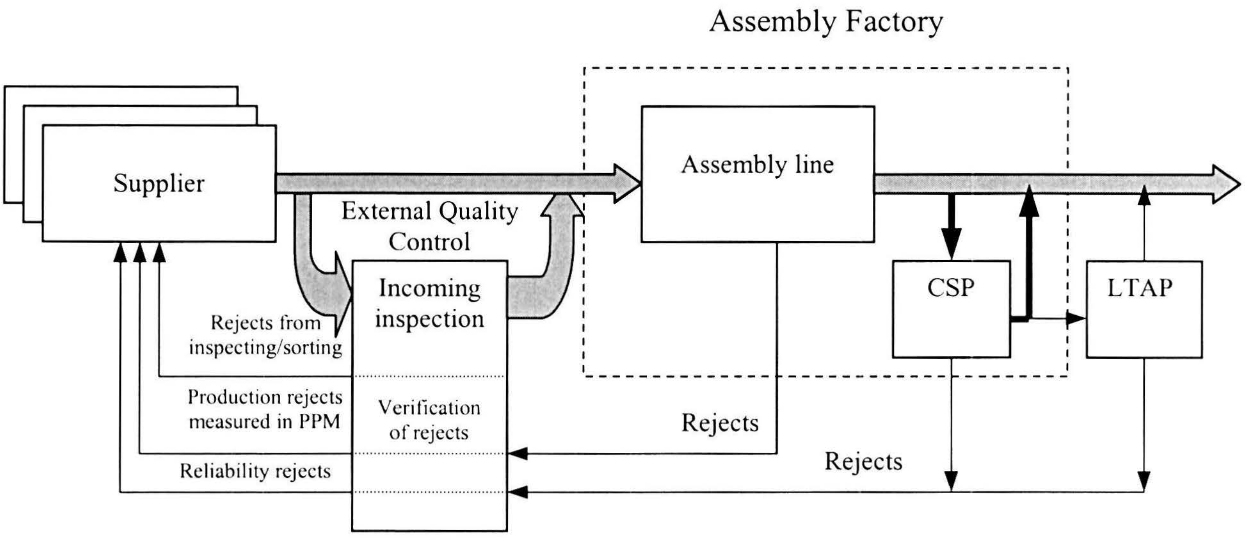
Appendices

Appendix A: External Quality Control and Assembly

The position of Assembly and External Quality Control within the quality control of supplied components and (sub) modules until finished products.



Customer Quality Control

Appendix B: Definitions

- *Reliability*

Reliability of a product is the probability that the product performs its functionality under stated conditions in a given timeframe.

- *Quality*

Classically, quality has been defined as the extent in which the product at deliverance conforms to the technical specification [13].
Lewis states quality as "the ability of a product to fulfil its intended purpose" [12].

- *Root causes*

The root cause is the most basic reason for an undesirable condition or problem, which, if eliminated or corrected, would have prevented it from existing or occurring [9]. Information on root cause level is detailed information that will lead to all dominant failures. This can be translated into repairs/modifications in current products and anticipated risks in future products [2].
Andersen and Fagerhaug [5] say "The root cause is 'the evil at the bottom' that sets in motion the cause-and-effect chain that creates the problem(s)".

Root causes should not be confused with primary and secondary location of failure. Primary (organisation); location of the cause within the business process (Development, Production, Operations, etc.). Secondary (position): location of the failure within the product (Hardware, Software, etc.).

- *Root cause analysis*

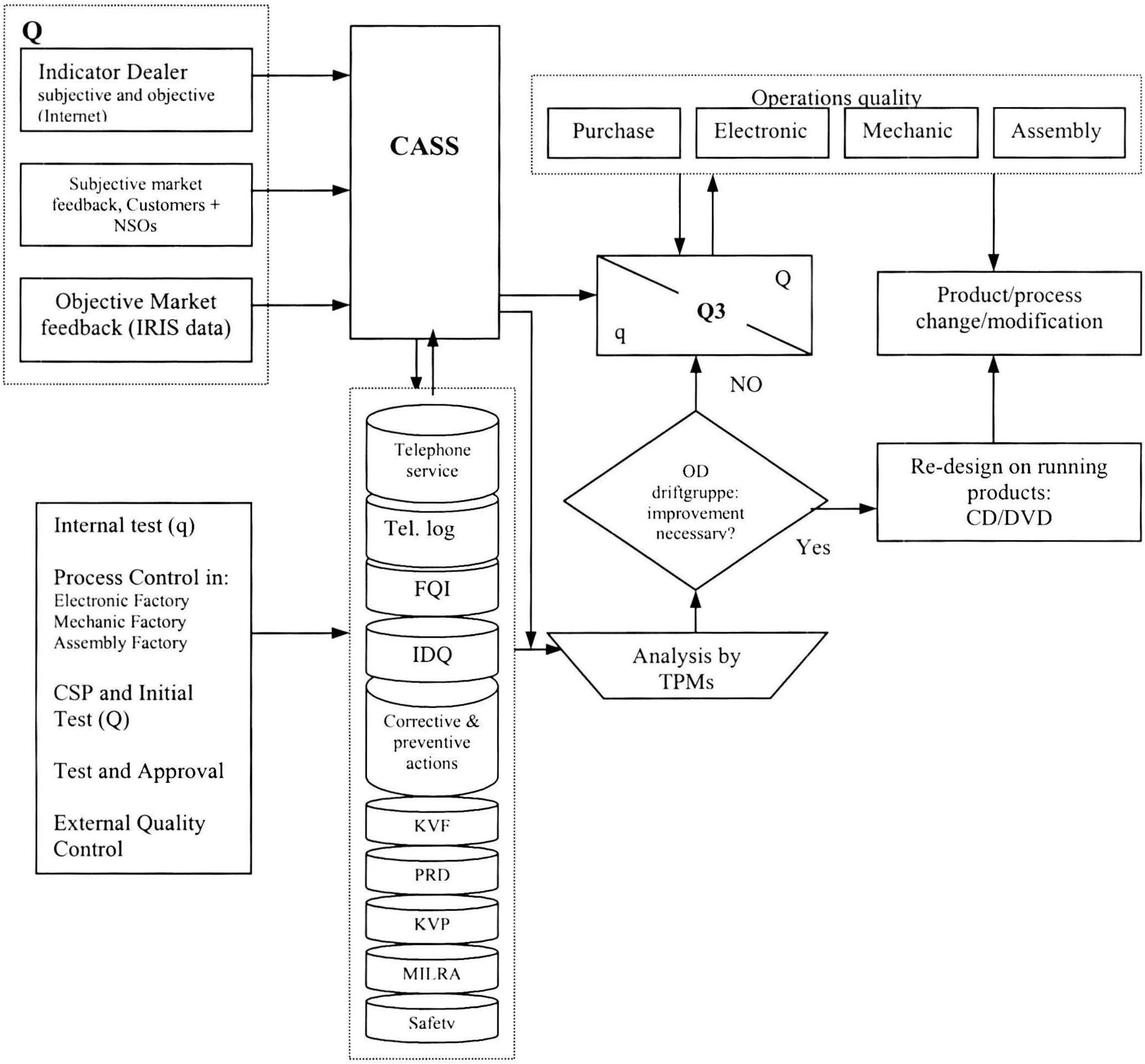
A variety of techniques, both informal and structural, that may be used to determine the (root) causes. Some RCA techniques are; change analysis, barrier analysis, Ishikawa diagrams, tree diagrams etc. Testing of failed products at functions and parameters is a method to determine the (technical) root causes.

- *Field Feedback information*

Field Feedback is information from the market from the point that a product leaves the factory to the moment a customer perceives a problem and contacts Bang & Olufsen. However, the focus in regard to field information is on the first contact between the customer who has a problem (via (Indicator) dealers, service centres, NSOs) to the moment the headquarters in Struer (Corporate After Sales Service / Technical Product Managers) are informed.

Appendix C: Flow diagram CD/DVD Driftgruppe

This flow diagram illustrates the information flow of field feedback and the position of the Technical Product Manager. Feedback from the field comes in at CASS, this feedback originates from customers, (indicator) dealers, or (national) service centres. The TPMs, who are responsible for a specific product range, use the field feedback, information from internal databases, and network information to decide about possible actions. This can be a deviation report that goes to the CASS meeting where is taking care after making a TOP10 list and a Market Quality Report. This information goes also to the Q3 meeting where is taking care after the progress of 'TOP list'-problems. The problems handled at Q3 are Quality-related product problems from the field and q3 handles the internal quality issues.
In the case of high impact field problems, the TPM has to contact involved parties to decide whether re-design activities are immediately necessary. In case of CD/DVD related issues this decision should be made by the CD/DVD Driftgruppe. Every member on its turn has to provide the information to his responsible manager that is representative in the Q3 meeting.



Flow diagram for CD/DVD related field quality problems

Appendix D: Abbreviations

CASS:	Corporate After Sales Service
EQC:	External Quality Control
NFF:	No Fault Found
RCA:	Root Cause Analysis
CEM:	Consumer Electronics Manufacturer
CCC:	Customer Contact Centre
CSP:	Continuous Sampling Plan
FFF:	Fast Field Feedback
NSOs:	National Sales Organisations
IDQ:	Indicator Dealer Quality
TPM:	Technical Product Manager
PD:	Product Development
PDCA cycle:	Plan Do Check Act cycle
KVP:	KValitetsopfølgningssystem for Produktion
KVF:	KValitetsrapportering på Færdigværeniveau
PCP:	Product Creation Process
AST:	Accelerated Stress Testing
HALT:	Highly Accelerated Life Test
HASS:	Highly Accelerated Stress Screen
MEOST:	Multiple Environments Over Stress Test
RMEOST:	Random Multiple Environment Over Stress Test
ppm:	parts per million
RPN:	Risk Priority Number
DKK:	Danish crowns
A/V:	Audio/ Video
IRIS:	International Repair Information System
FQI:	Field Quality Information
OD:	Optical Disc
FMEA:	Function Mode and Effect Analysis
QFD:	Quality Function Deployment
FTA:	Fault Tree Analysis
CWQC:	Company Wide Quality Control
PLC:	Product Life Cycle
HR:	Human Resources
IT:	Information Technology
PR:	Public Relations

Appendix E: Market quality priority list

The market quality list represents field problems, to which weighted scores are allotted to prioritise the quality problems.

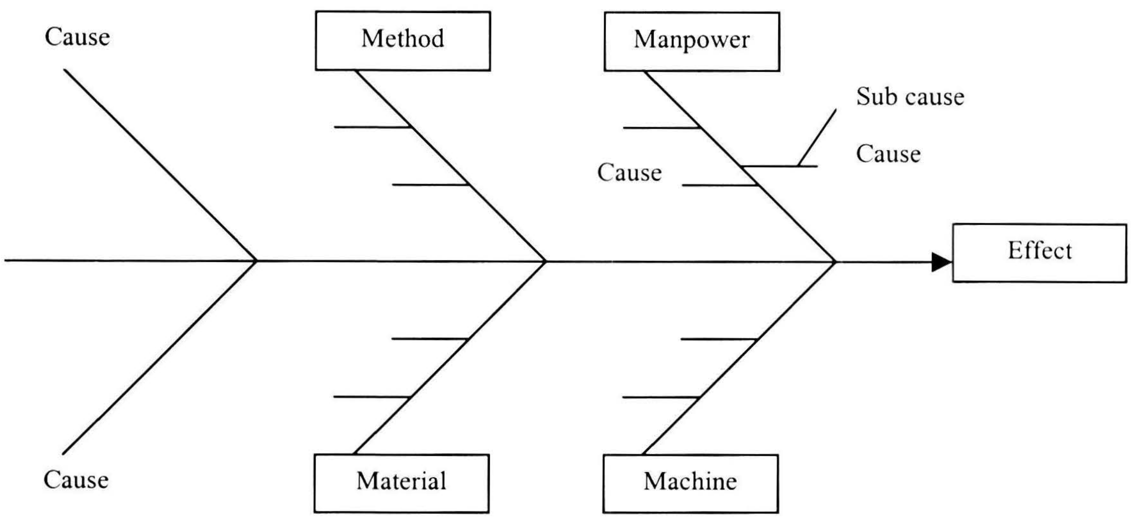
Q3 Market quality priority list Parameter	Seriousness	Impact	Loss of image	Relation to more products	Cause to more symptoms	Unexpected or unacceptable	Price of reparation	Stage within PLC	Total score
Weight	10	20	3	3	5	6	4	2	
Scale: 0-40									
BeoSound 9000,jump tracks	35	30	20	5	15	30	30	30	1460
Avant, picture quality	36	28	36	28	28	12	8	12	1380
BeoCenter 1, skips a program	2	8	2	0	0	5	0	30	276

Q3 Market quality priority list

Appendix F: Tools and methods

- **Ishikawa diagrams**

1) Ishikawa diagrams [14], also called cause and effect diagrams or fishbone diagrams, can help in structuring cause and effects of a problem. The technique consists of defining an occurrence or problem (effect). Once the effect is defined, the factors that contribute to it (causes) are outlined. These are the possible reasons that the problem exists. While there may be only one actual cause to a problem, there are probably many potential causes that could appear. As the purpose of using an Ishikawa diagram is to understand the factors affecting a process, the diagram must present the perspective of many different people involved in the process.



Ishikawa diagram

Advantage is that the method can identify faults systematically if a process is chaotic and the causes of these failures are clearly shown in the diagram. It enables analyses to organise and structure different sources of information. Besides it forces the group of analysts to understand the system. A disadvantage that is shared by all risk analysis is oversight and omission. There is always a possibility that significant failure modes are overlooked in the system.

- **Fault tree analysis**

Fault tree analysis (FTA), this technique is to a large extent comparable to the fishbone diagrams. The difference with FTA is that Ishikawa diagrams are not set-up to be suitable for quantitative analyses. Besides, where FTA is more aimed at probing a cause to the bottom, Ishikawa diagrams lay more emphasis on the identification off all possible causes.

- **Quality Function Deployment**

Quality Function Deployment (QFD) is based on the concept of company wide quality control (CWQC) [25]. Customer orientation, cross-functional management and process rather than product orientation characterise the CWQC philosophy.
Customer's requirements and their relationships with design characteristics are the driving forces of QFD methodology. The quality and reliability of a product are predominantly determined in the early phases of the development process. QFD enables an organisation to "build" quality into the product and to control the development process from concept to the commencement of manufacturing operations. In the "House of quality", the different steps of the planning phase for a new product are summarised. During this phase the customer

requirements (WHAT) are translated into design characteristics (HOW) on the basis of market research and past experiences (the WHY scores). Of all the steps in the total product development process, non-deserves more attention than the definition of the *right product* for the *right customer*. This means that management has to establish a clear product policy that should provide specific guides for intended product quality and market penetration.

- **Failure Mode and Effect Analysis**

FMEA provides a systematic way of identifying faults and assessing the risks, associated with failures and faults. A risk analysis method like Ishikawa diagrams is needed before a FMEA analysis can be carried out. The added value of FMEA is the quantification of the risks in a risk priority number (RPN) and the possibility this gives for planning of follow up actions. The effectiveness of these follow up actions can be evaluated by calculating a new risk priority number after a follow up action.
Teamwork is critical to the success of the FMEA process. The team to perform FMEA should include customers, manufacturing engineers, test engineers, quality engineers, reliability engineers, product engineers, and sales engineers.
There is a standard form almost universally used to carry through the analysis, the *FMEA procedure* [26].
There are two phases in the FMEA process. The first phase is to identify the potential failure modes and their effects. The second phase is to perform criticality analyses to determine the severity of the failure modes. The first phase has to be done concurrently with the detailed product design. It should also include defining the possible failures of the product's components, sub-assemblies, final assembly, and its manufacturing processes. At the end of the first phase, the detailed design is completed, and the design drawing is developed. At the second phase of FMEA, engineers in the FMEA team evaluate and rank the criticality of each failure, and then revise each design detail and make required modifications. The most serious failure has the highest rank and is considered first in the design revision. The design is revised to ensure that the probability of occurrence of the highest ranked failure is minimised. The first phase is from information gathering to the calculation of risk priority numbers (RPNs). The actions in the second phase contain the ranking of RPNs, the recommendation of corrective actions, and the modifications of the design. At the end of the procedure, an FMEA report can be obtained, and the required modifications are completed to reduce the number of the potential failure modes to the minimum.
Bang & Olufsen has also a weighted scoring procedure to prioritise quality and reliability related (field) problems, called the Q3 market quality priority list.
FMEA gives point to failure modes at three scales:

1. Seriousness of the consequences
2. Frequency (or probability) of the cause occurrence
3. Correctability of the cause

However, Bang & Olufsen gives weights to rank a number of field problems, the problems are ranked in relation to several parameters that have each a weighted score of importance (app. E).

Appendix G: CD playability problem

In December 2000 the BeoSound 1 was released in Europe and shortly afterwards in the USA. At the end of January 2001 failure reports arrived in Bang & Olufsen of the BeoSound 1 having playability problems in the USA. Two weeks later a report from Australia showed the same playability problems with the BeoSound 3000. The problem could be expected to occur with other brands also, because the playability problems occurred with CDs that did not conform to 'Red Book' standards. However, Bang and Olufsen is not using the mainstream CD mechanisms of the critical supplier, but a 'higher-end' one that was expected to have a longer lifetime. Bang and Olufsen and the Jukebox branch are the only ones using this CD mechanism and accordingly are also the only ones suffering this problem.
A Root Cause Analysis by Product Development and the supplier showed the cause of failure. A different resistor value combined with next version software solved the problem and changes were made in production.
A delivery stop to the USA was necessary together with a service solution. The stock of BeoSound 1 in Australia could be upgraded just before release.
This example shows that the length of the PLC phases and the moment of failure is important in what kind of actions are necessary and possible after a product failure. Re-design of the CD mechanism and a service solution for the products at the market were needed in this example. However, the knowledge of this problem can be used to anticipate quality risks in next product generations.

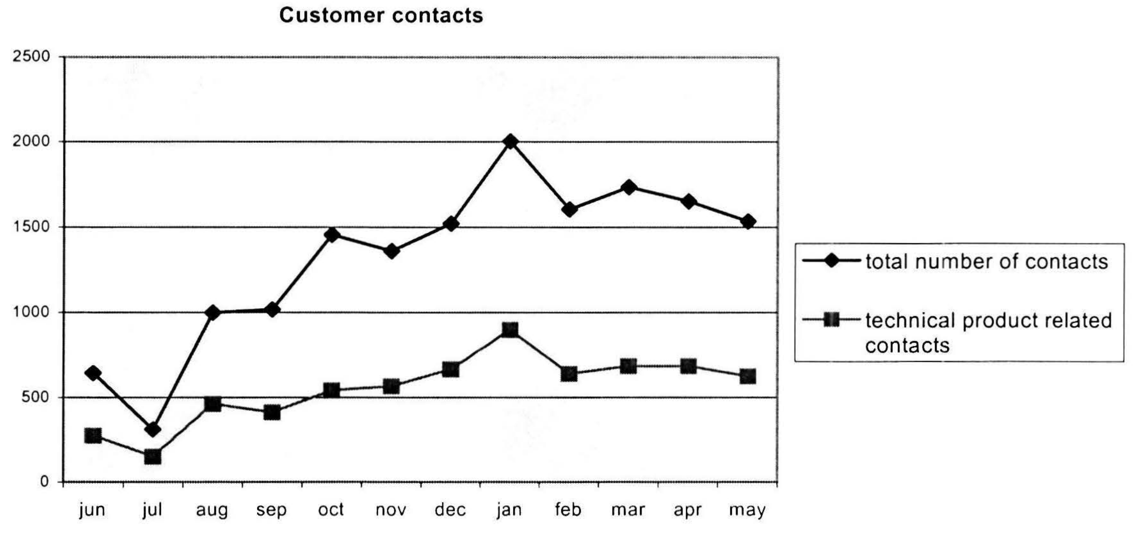
Appendix H: Customer Contact Centre

This section describes the Customer Contact Centre and the categorisation into parts. Also the information has been compared with Indicator Dealer contacts.

Customer Contact Centre

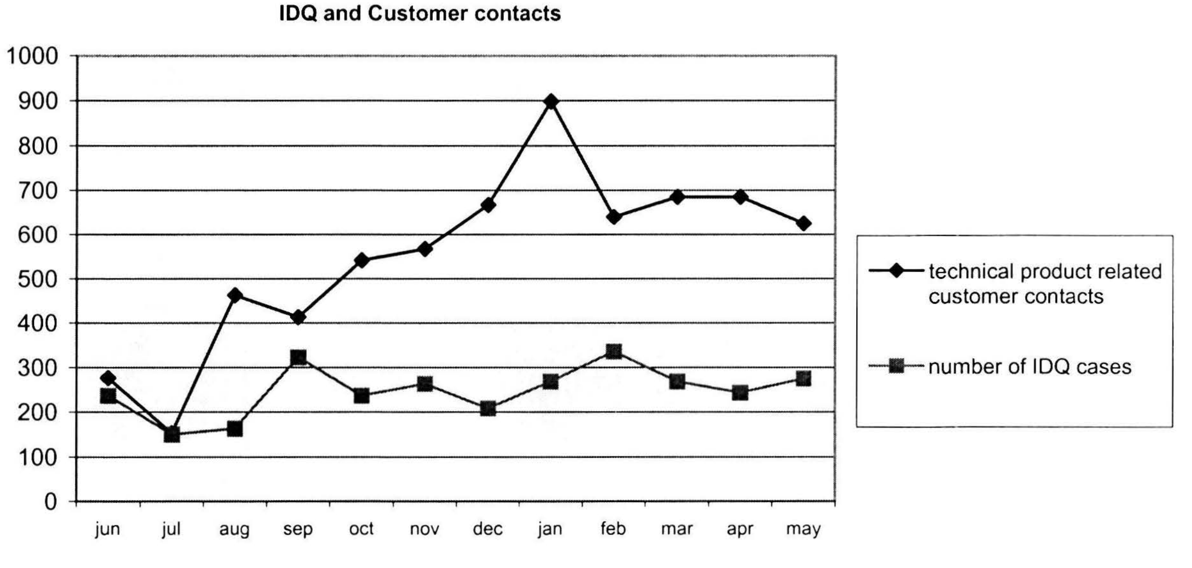
- The time that the CCC handles the cases is quite fast (within one day for emails, a two-day time period for faxes, 5 working days for letters and immediately for phone calls).
- However, the time elapsed before the contact has been made and the customer had a problem is difficult to estimate. No statistics are available of this, because the first priority of the CCC is servicing the customer when the contact is made. What time elapsed before the contact was made is not important with respect to servicing purposes, however, this is important with regard to fast field feedback. The field information from the Customer Contact Centre is not structurally used and suitable for a root causes analysis.
- The categories of the contacts are for a major part not product related. Only the technical product related contacts have value with regard to the right information at the right time.
- The technical product related information of the CCC is categorised in a number of groups:

  -accessories　　-operation
  -compatibility　　-repair assistance
  -installation　　-spare parts
  -modification　　-specification



Total number and technical product related contacts

The number of contacts with the CCC is still growing especially caused by the increasing growth of email contacts. The technical product related contacts are a considerable part of the total number of contacts.



IDQ and technical product related customer contacts compared.

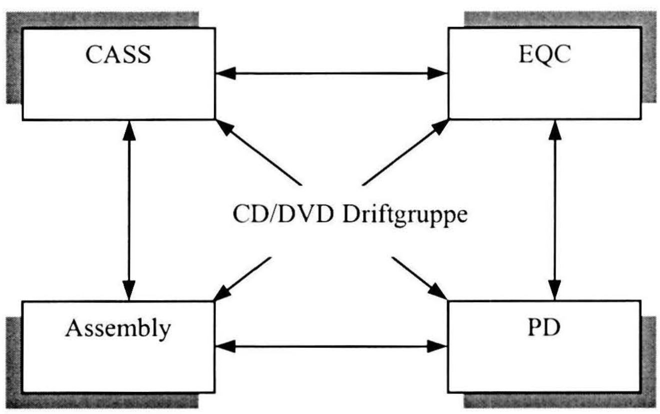
Although the number of IDQ cases is smaller than the technical product related customer contacts, IDQ provides field information about product behaviour. This provides fast field information and therefore IDQ is more valuable than the customer contacts with regard to the right information for fast field feedback.

Appendix I: CD/DVD Driftgruppe

The relevancy of the CD/DVD Driftgruppe in relation to the project can be explained with regard to paragraph 3.5 "product quality improvement". Where the importance of getting field information at the right time is focused at level 1, the CD/DVD Driftgruppe is the working structure that is responsible for the complete handling and coordination of all CD and DVD related problems, included field problems. The group's main purpose is to anticipate quickly on product problems by processing the information and execute a Root Cause Analysis (level 2). The working structure is also responsible for initiating and facilitating necessary follow-up actions (level 3).

The CD/DVD Drifgruppe consists of six representatives from the departments Product Development, CASS, EQC and Assembly (app. A).

- CASS has two TPMs as representatives in the group and their responsibility is to be on the alert for CD/DVD related problems from the field and gathering the relevant information to facilitate the root causes analysis.
- The representative of External Quality Control (EQC) is the contact with the supplier of the CD and DVD mechanisms used in the Bang & Olufsen products.
- Assembly has also two representatives and they have to provide the CD/DVD Driftgruppe with information regarding problems in production.
- The task of the Product Development' representative is to provide the technical information that is relevant in root causes analysis and problem solving. PD is also the main department for possible re-design activities, in case of production, field or other problem issues.



CD/DVD Driftgruppe and the representative departments

Main advantages and tasks of the CD/DVD Driftgruppe:

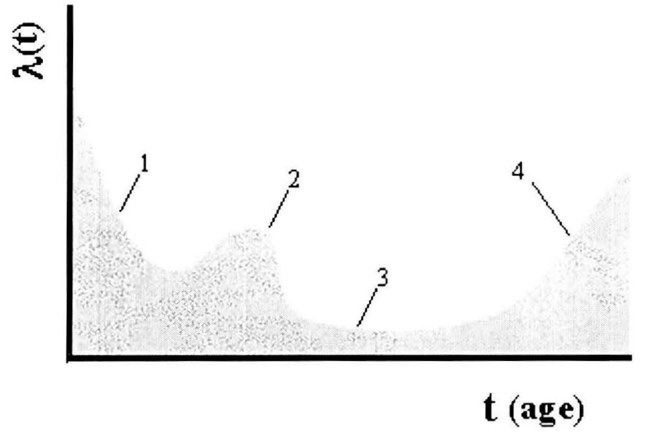
- Multi/cross functionality; all the relevant departments have representatives in the Driftgruppe and this makes them very suitable to decide how urgent problems are and how to solve/handle it.
- Fast; the Driftgruppe is small what facilitates a fast meeting and reporting structure.
- Processing the field information; although the CD/DVD Driftgruppe does not provide faster field feedback than in the normal routine, it facilitates faster processing of field

information. By performing activities in parallel and using the group's know-how and expertise a (potential) problem can be handled fast.

- Ensuring the learning loop; by sharing experiences and knowledge from different points of view, the individual members can increase their know-how. The Driftgruppe as a whole is also getting more experienced and can rely on a broader knowledge base in handling the CD/DVD problematic (CD/DVD Driftgruppe database).
- Preventing sub-optimisation; without close cooperation between the departments Product Development, Assembly, CASS and EQC there is a risk that each separate department optimises its own task. Optimisation in one department, however, can cause problems in other parts of the organisation. For example a highly styled product developed by PD can have serious repercussions on ease of assembly and resulting in a low reliability of the product in the field.

Conclusion
The formation of this technical coordination group that closely follows-up at CD/DVD related problems that occur in production and in the field is cross functional and therefore suitable to judge and solve problems or to initiate improvement actions.
Another interesting aspect is that the basic idea of this group could be generalised. (1) For other products and/or technologies, (2) to carry all kind of improvement projects, which affect several departments, (3) as close follow-up group after product launches, or (4) as a team that performs the RCA of field failures.

Appendix J: Four-phase Roller Coaster Curve



1) Hidden 0-hour failures: Product that arrives out-of-specifications at the customer. These products have either slipped through final tests, have been damaged during transport or are used in an unanticipated manner.
2) Early wear-out: For high-volume consumer products it is not unlikely that there are considerable differences between either any two items of a product or between how any two customers will use the same product. In some cases this can lead to situations where a distinct sub-population of products shows different reliability behaviour than the main population with respect to wear. Examples are products that are produced with internal flaws. These flaws can cause a far faster wear-out that the main population. In the failure rate curve these sub-populations can appear as one or more "humps". 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 use 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. Although many of these events have a comparatively low probability, these rare events can always happen. In those cases where the likelihood of occurrence for these events is constant in time and constant over the product population the effect will be a constant failure rate.
4) Systematic wear-out: Many products show some form of degradation over time. Well-known time effects are corrosion of metals and increased brittleness of plastics. Although the level of degradation will be different for every product in a large population there will be a moment in time when the first product fails due to degradation and a moment when the last product has failed. At the moment in time where these failures start to dominate the failure rate curve it will lead to an increasing failure rate.

It is important, however, to emphasise that phase 1 and phase 2 failures occur in distinct sub-populations of products (or product users) and phase 3 and 4 are relevant for the entire product population.