MASTER

A case study into increasing warranty costs in the Lighting Electronics industry

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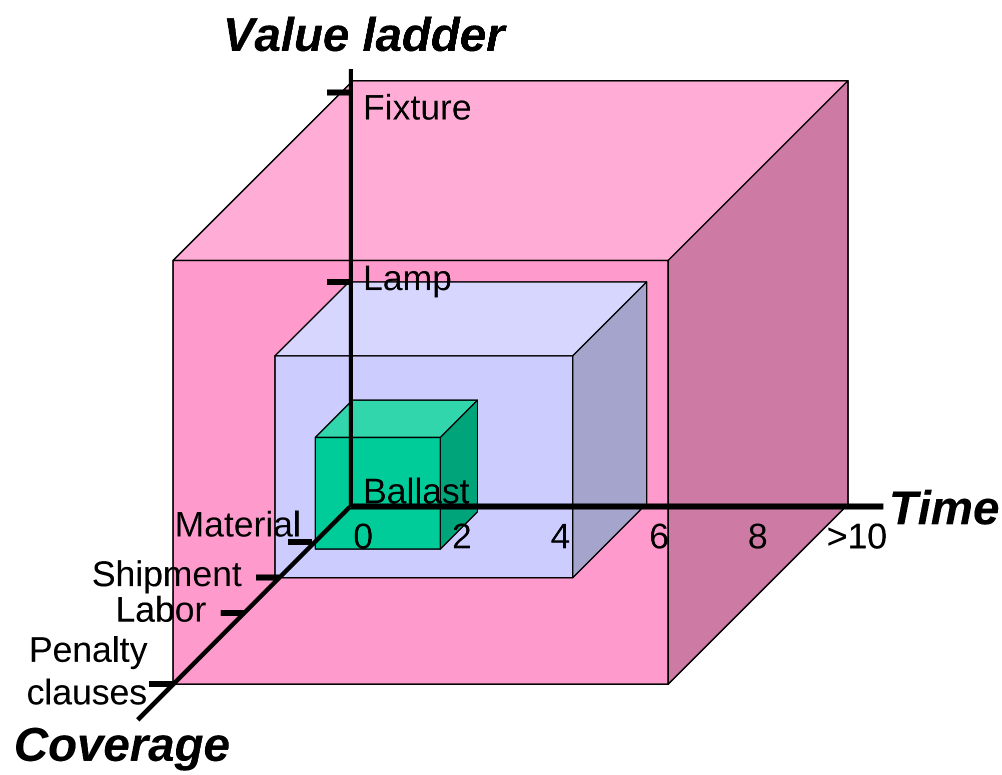

Representation of the warranty boxes model [Wij 07]

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I started the study to “fill the gaps” in my knowledge on statistics, supply chain management, quality management and more typical business engineering areas.
Starting the technical business engineering study I never expected what efforts considering time and intellectual challenges would be requested from me.

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Summary

Since the early days of industry much has changed. One thing didn't: the main challenge of keeping customers satisfied whilst still meeting company internal financial ambitions.

The electronics industry is witnessing an increase in the number of complaints. Literature shows several trends that influence the number of customer complaints. This literature is mainly based on high volume consumer electronics products in a retail environment.
This thesis tests if the same trends are found in a business-to-business environment in a different part of the electronics industry.

The following hypothesis is tested:
In a lighting electronics business-to-business environment as well as consumer electronics retail environment an increase in customer complaints is found.
This is caused by several trends leading to a growing number of products that are not satisfying the customer needs and expectations.
The absence of a well functioning field feedback system to learn from customer experience and behavior further amplifies this increase.

The test is done via a case study at a large lighting electronics company witnessing an increase in its out of pocket warranty costs.

Via interviews, literature studies, data collection and analysis information is gathered to test the hypothesis on the case study.

The results of the case study hypothesis:

a) Positive test on increase in customer complaints at lighting electronics business-to-business environment
b) Positive test on the applicability of the found trends. No test done on correlation of each separate trend with increase in complaints. However the case study did bring forward strong clues that such a correlation does exist e.g.:
   - Malfunctioning components from an external supplier resulted in system failures which resulted in an increase in claims and complaints;
   - Changes in technology from electromagnetic to electronic resulted in less robust products which resulted in system failures and increase in complaints;
   - Different warranty conditions result in different number of complaints
c) Positive test on absence of well functioning field feedback system. Positive test on not learning from customer behavior. The case study company does learn from customer experience but not to its full content. So that part of the hypothesis could not be fully confirmed.

Therefore after the test the hypothesis can be translated into the following statement:

In a lighting electronics business-to-business environment as well as consumer electronics retail environment an increase in customer complaints is found.
There are several trends and combinations of trends that very likely cause this increase.
The absence of a well functioning and mature field feedback system to learn from customers' experience and behavior contributes to the increase.

Following industry general recommendations are made:

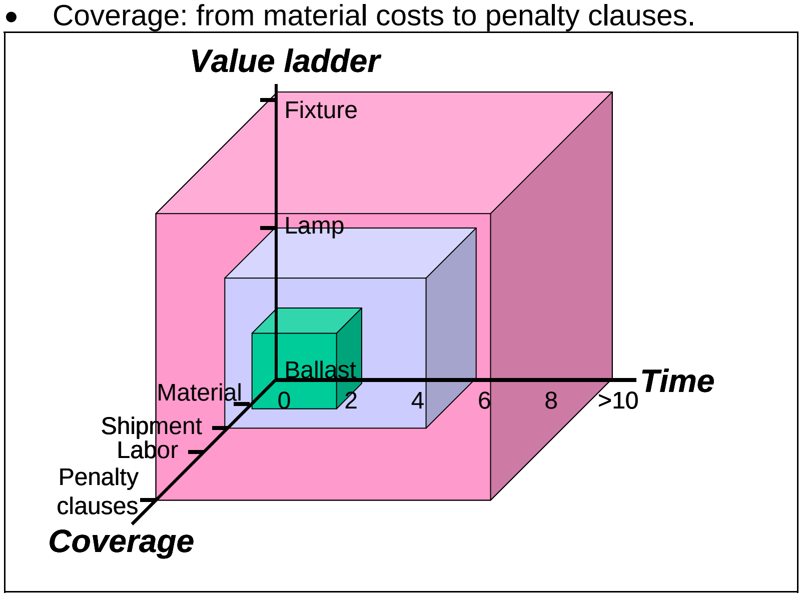
- Companies should take benefit from understanding the backgrounds of the trends and be pro-active in using this in their customer contacts.

The two trends "Changing warranty conditions & timely field feedback availability" have the highest correlation to the thesis' scope.

- Organizations should create a field feedback system aimed at retrieving that information that provides an insight in what is happening at the customers' site.
- Furthermore the feedback from the field should be processed to all relevant organizational entities / business processes without any time gap.

A warranty box model is created to plot warranty conditions on three axis:

- Time: warranty coverage from 0 up to and over 10 years;
- Value ladder: from products only to full systems;
- Coverage: from material costs to penalty clauses.



- Organizations should first picture their warranty policy onto the warranty box model and next include their product failure probability distribution and the failure distributions of other elements (lamps, fixtures) from the value ladder. The extension of coverage from the product into next levels, should be done only when field feedback information predicts that the increased sales outgrow predicted warranty costs increase. The organizations with the most accurate field information and the best field feedback loops, reaching the deepest into the organization, will have a serious advantage on other organizations. For sure an increase on the time axis will have serious effects on warranty costs in case the coverage axis is increased outside products only. Therefore it is highly recommended not to run a "me too" policy on warranty.

- It is advised to further research how to set warranty conditions should for product-market combinations and for specific applications with their unique physical environment.
- Recommendation is to maintain a test platform to be able to detect in-product failures that can be related back to all stakeholders (design/ supply/ manufacturing/ consumer). As a next level organizations should ensure to retrieve actual application information. Either via own or independent service organizations or by requesting the “claimer” to provide actual application information (like fixture temperature, wiring pictures, humidity measurements, lamp and fixture details, power measurements). Not only will this information provide input for a full root cause analysis; it also creates a possibility to refine product specification in order to create more robust products, capable of withstanding more violent operating conditions and acting as a net for less reliable lighting system components (lamp, fixture, controls, power supply).
- In order to simplify the warranty/complaint handling process on one hand and shifting focus from only costs to costs and customer satisfaction, organizations need to learn more and faster what issues arise in the field. Fast field feedback, preferably recovered by own or hired organizations, holds the key to that end.
- Organizations should ensure identification of products gets done fast and with a number of attributes (e.g. via bar-coding).

Samenvatting

Vanaf de start van het industriële tijdperk is er al veel veranderd. De hoofduitdaging is echter hetzelfde gebleven: hoe houd ik mijn klanten tevreden zonder het bereiken van mijn interne financiële ambities in gevaar te brengen.

De elektrotechnische industrie ervaart een toename in het aantal klachten. De literatuur geeft enkele trends welke deze toename beïnvloeden. Deze literatuur is voornamelijk gebaseerd op onderzoek in de consumenten elektronica.
Dit onderzoeksrapport toetst of de trends uit de consumenten elektronica ook van toepassing zijn op een “business-to-business” omgeving.

De volgende hypothese werd getoetst:
In een lighting elektronica “business-to-business” omgeving alsmede in een consumenten elektronica omgeving wordt een toename in consumenten klachten ervaren. Dit wordt veroorzaakt door een aantal trends welke leiden tot een groeiend aantal producten die niet langer voldoen aan de wensen en eisen van de klant.
De afwezigheid van een goed functionerend systeem om klant ervaring en klantgedrag terug te krijgen in de industrie zorgt voor een verdere toename van deze consumenten klachten.

De toets werd uitgevoerd door veldonderzoek bij een grote Licht elektronica onderneming. Binnen deze onderneming ervaart men een toename in de betaalde garantiekosten.

Via interviews, literatuur studies, data verzameling en het analyseren van gegevens is informatie verkregen om de hypothese te toetsen.

De resultaten van de toets:

- Positieve op de toename in klantenklachten in een licht elektronica “business-to-business” omgeving
- Positief op de gevonden trends. Er is geen toets uitgevoerd op de correlatie tussen de individuele trends en de toename in de klachten, hoewel er wel sterke aanwijzingen zijn dat een dergelijke positieve correlatie bestaat. Enkele voorbeelden van dergelijke aanwijzingen:
  - Falende, extern geleverde, componenten resulteerden in licht systeem falen. Dat resulteerde in een duidelijk waarneembare stijging van het aantal klantklachten;
  - De verandering van elektromagnetische producten naar elektronische producten betekende een overgang naar minder robuuste producten. Daardoor nam het aantal falende licht systemen toe wat heeft geresulteerd in de toename van het aantal klantklachten;
  - Verschillen in garantievoorwaarden en –condities heeft leidt tot een verschillend klachtenpatroon.
- Bij het veldonderzoek werd geconstateerd dat een goed functionerend “feedback” systeem ten aanzien van klantengedrag en klantenperceptie ontbrak. Er wordt onvoldoende geleerd van klantenperceptie.

De toetsresultaten hebben geleid tot de herziening van de hypothese naar de volgende stelling:

In een lighting elektronica "business-to-business" omgeving alsmede in een consumenten elektronica omgeving wordt een toename in consumenten klachten ervaren. Er is een aantal trends welke hoogstwaarschijnlijk deze stijging kunnen verklaren.
De afwezigheid van een goed functionerend systeem om klant ervaring en klantgedrag terug te krijgen in de industrie draagt bij aan deze stijging.

Het veldonderzoek heeft geresulteerd in een aantal aanbevelingen:

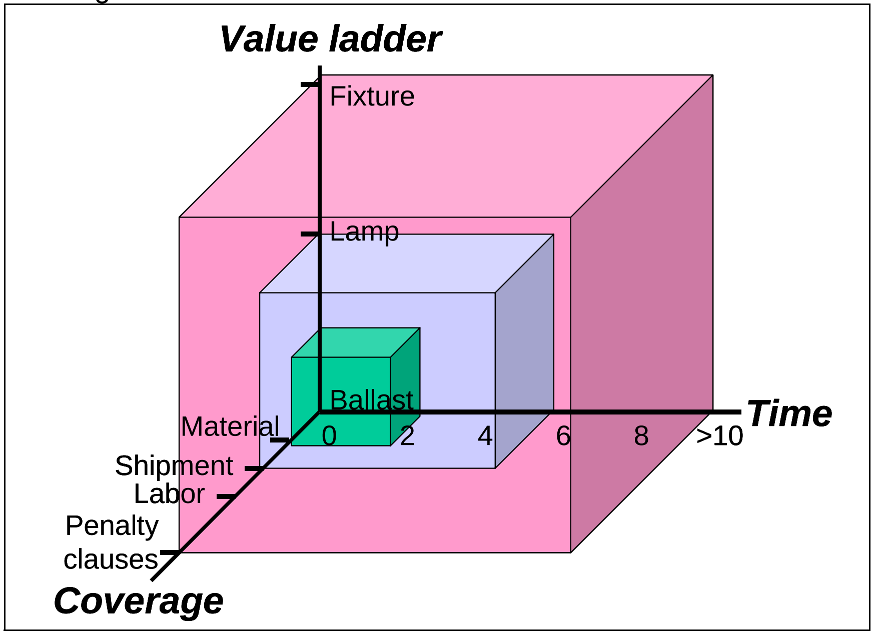
- Bedrijven moeten de achterliggende oorzaken achter de trends begrijpen en deze oorzaken pro-actief gebruiken bij het benaderen van hun klanten.

De twee trends "veranderende garantievoorwaarden" en "tijdige beschikbaarheid van veldinformatie" hebben de grootste correlatie met de afbakening van dit onderzoek.

- Organisaties moeten een systeem opzetten om snel informatie vanuit de markt terug te koppelen in het bedrijf. Die informatie moet inzicht verschaffen in wat er precies gebeurt met de producten wanneer deze bij de klant in werking zijn.
- Daarnaast moet deze terugkoppeling onmiddellijk en zonder tijdsverlies plaatsvinden naar alle relevante bedrijfsonderdelen.

De onderzoeker creëerde een garantie dozen model waarin op drie assen de garantievoorwaarden worden weergegeven:

- Tijd: garantie wordt gegeven voor een periode van 0 tot meer dan 10 jaar;
- Waardeketen: van ballast tot volledig licht systeem;
- Dekking: van materiaal kosten tot boete clausules.



- Bedrijven moeten starten met hun garantievoorwaarden in het model te plaatsen en daarna de kansverdeling van het falen van hun product en de kansverdeling van de andere elementen (lampen, armaturen) van de waardeketen.
- De uitbreiding van dekking van enkel product tot meer niveaus mag alleen maar worden gedaan wanneer informatie uit het veld voorspeld dat de toename in verkoop als gevolg

van die uitbreiding groter is dan de toename in garantiekosten. Die organisatie met de meest accurate veld informatie en met het beste terugkoppelsysteem welke het snelst en best aan de bedrijfsonderdelen is gekoppeld zal een belangrijke voorsprong hebben op haar concurrenten.

- Een uitbreiding van de dekking op de tijdsas zal een significant effect hebben op de garantiekosten wanneer de dekkingsas uitgebreid wordt voorbij de producten. Het wordt daarom afgeraden om een "ik ook" beleid te voeren waarbij de garantievoorwaarden en de dekking klakkeloos van anderen wordt gekopieerd.
- De onderzoeker raad bedrijven aan om verder onderzoek te doen naar welke garantievoorwaarde en –dekking het beste past bij ieder van de product-markt combinaties van het bedrijf. Het wordt daarbij aangeraden om rekening te houden met de toepassing/applicatie en de fysieke omgevingscondities. Door een goede productidentificatie (streepjescode) kan het snel verkrijgen van de juiste productinformatie aanzienlijk worden vereenvoudigd.
- Verder wordt aanbevolen om een testcentrum op te zetten / aan te houden voor het testen van producten welke onder garantie worden teruggestuurd. De informatie uit dit testcentrum kan gebruikt worden voor het vinden van product/component fouten. Daarnaast wordt aangeraden om actief veldinformatie te verkrijgen. Hetzij door als bedrijf zelf service organisaties in beheer te nemen of door het afsluiten van een contract met een service organisatie. Deze service organisatie biedt het bedrijf de mogelijkheid om actuele fysieke condities (temperatuur, luchtvochtigheid, bedrading, lamp en armatuurcondities) in de applicatie te toetsen. Als een (minder) alternatief kan de klant zelf gevraagd worden deze condities te toetsen. Deze toets geeft niet alleen veel betere applicatie informatie voor verdere hoofdoorzaken van het falen van een lichtsysteem, maar veel meer nog biedt het de mogelijkheid om productspecificaties beter af te stemmen op de applicatie condities. Daarmee kunnen de producten meer robuust worden ontworpen zodat ze beter instaat zijn om "vijandige" lichtsysteem" condities te weerstaan en om op te treden als een vangnet voor minder betrouwbare lichtsysteemonderdelen zoals de lamp, het armatuur en de energievoorziening.
- Organisaties moeten snelle terugkoppeling van veldinformatie in de organisatie waarborgen om zodoende het garantieproces en klachtafhandelingssysteem simpel te houden en om de blik gericht te houden op kosten en klanttevredenheid.

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Chapter 1 Introduction

The first chapter gives an outline of the set up of the thesis.
Chapter 2 describes, via the identification of trends in literature and the electronics industry why the number of customer complaints shows an increasing trend.
Chapter 3 brings forward a first research hypothesis derived from the described trends and specified for a business-to-business situation. Furthermore the chapter contains a description of the research approach and it introduces a case study.
In chapter 4 information derived from interview sessions within the company where the case study took place is processed into a final research hypothesis.
Chapter 5 contains the findings out of a literature study to create a theoretical framework based on information on existing complaint-handling systems in general and field feedback systems in particular. This theoretical framework serves as the basis for the case study.
The 6th chapter contains the set up of this field study.
In chapter 7 the results of the research steps are shown.
Chapter 8 outlines the conclusions and recommendations.
Finally the report contains a list of used literature.

Several annexes contain information that is not available for the public at large. Therefore these annexes are made available to the examination committee only.

Chapter 2 Context

This chapter introduces an industry wide challenge: keeping customers satisfied whilst still meeting company internal financial ambitions. In the first paragraph several trends are introduced that influence the number of customer complaints.
The second paragraph combines the trends into a first research hypothesis.

2.1 Relevant trends in literature and the electronics industry

One can distinguish several main trends in the industry influencing the trade-off between product pricing & functionality and product quality & reliability and as such having its influence on the number and kind of customer complaints.

Lu [Lu 02] described four main trends:

- Fast technology innovation (based on Goldhar et al., 1991; Wheelwright and Clark, 1992; Nijssen et al., 1993; Birnbaum, 1998; Minderhoud, 1999; Brombacher and de Graef, 2001),
- Increasing globalization and segmentation (based on Classen and Lopez, 1998; Murthy et al., 1994; Brombacher and de Graef, 2001) in product development activities,
- Increasing complexity in customer requirements and perceptions over product performance (based on Goldhar et al., 1991; Wheelwright and Clark, 1992; Brombacher and de Graef, 2001),
- Increasing pressure on time-to-market (based on Stalk and Hout, 1990; Goldhar et al., 1991; Wheelwright and Clark, 1992; Minderhoud, 1999)

Other publications [Bro00,01,05], [Mol02], [San99] describe a few more trends.

All these trends are described in a little bit more detail below.

1. Globalization and price erosion
Globalization of the marketplace has led to more focus on costs. Where in the past products were provided and supplied on a local-for-local basis, customers now more than ever can purchase their products from a globally operating industry [Lu 99]. This led to continuous price erosion as a result of manufacturers driving to reach lower production costs and customers demanding decreasing prices.

2. Outsourcing / sub contracting of activities
Outsourcing entails the concept of taking internal company functions and paying an outside firm to handle them. NelsonHall defines business process outsourcing as the outsourcing of business functions or processes, such as procurement, to a third party. In these contracts the provider is responsible for performing and managing the outsourced function or process on behalf of the customer. In order to qualify under this definition, Business Process Outsourcing contracts must involve the provider taking overall responsibility for the business process.

Outsourcing is done to save money, improve quality, or free company resources for other activities.
Outsourcing significantly increases the need for co-operation between departments, both internal and external [Pet 03]. Although outsourcing can increase the companies flexibility according to Petkova outsourcing risks concern: not being able to deliver in time, incomplete specifications to loss of knowledge and skill.

3. Speed of development
One can witness a demand for shorter development throughput times, now that the market has become a time-driven market. The innovation speed is becoming an important factor for company success. Over the last decades the speed to bring new technology to the market has increased considerably [Lu 99]. The time required to learn about the actual performance and perception of this new technology has not been reduced at equal pace [Bro 04]

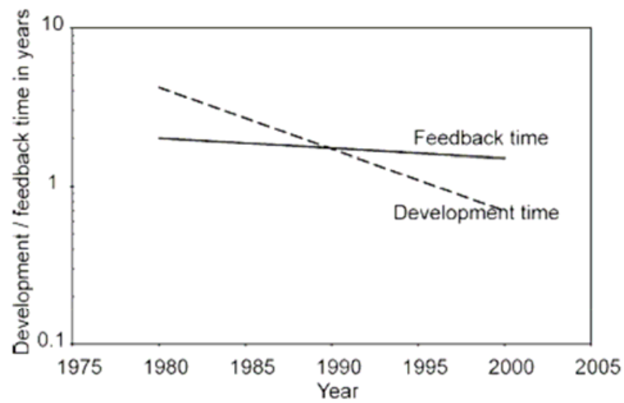


Figure 1-1: Development time versus feedback time for high-volume consumer electronics [Bro 04]

In a world where it is growing more difficult to distinguish oneself from competition the need for technological innovations and the creation of new, added value, products are becoming increasingly important. This has resulted in the need for an increasing speed of development of product successors and new products. This means: short development times, faster time-to-market and time-to-profit.

4. Increasing product functionality and complexity
The need to be innovative conjoined with release of technological knowledge has created more possibilities for new products [Lu 99]. In the meantime consumers demand compatibility to existing technologies, a high degree of functionality, ease of use and interconnectivity with other products.

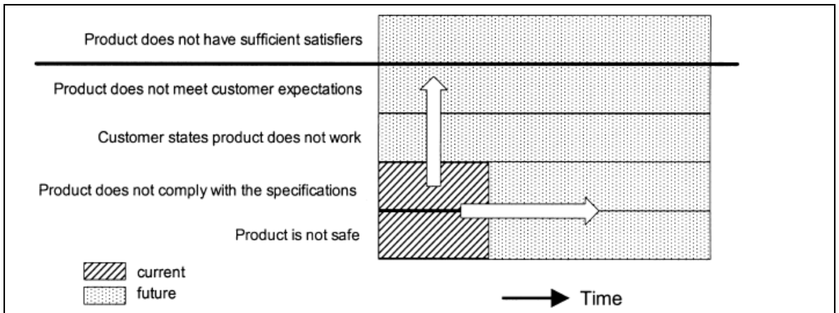
5. Changing Customer demands
Customers' demands on quality and reliability have been increasing [Lu 99]. In an increasing volatile business in order to ensure products carry enough satisfiers companies need to focus on more than products that are “safe” and within specifications. The tolerance of consumers and end-users for quality and reliability problems is decreasing [Oud 06]

6. Changes in warranty legislation and warranty terms
Manufacturers and providers have a broader responsibility for the behavior of their products during a longer period.
Warranty periods have increased from 6 months to 3 years and more. In industries like car manufacturing warranties of 10 years on several car parts are common practice. Not only the warranty period itself has changed, also the coverage changed. In the past warranty was restricted to replacing defective components, now several companies are running a no questions asked policy by which the customer can return the product and exchange it for a replacement free of charge [Bro 01]. To ensure warranty costs will not see an increase companies need to at least assure a constant quality and reliability level.

To avoid high warranty costs, in innovative fast product development processes, such as consumer electronics, it is necessary to check as quickly as possible, using field data, whether the product reliability is at the right level [Rox 07].

Many companies consider warranty terms and conditions as a sales argument and act upon this by lengthening the warranty period well above current levels and by adopting all kind of other benefits.
As far as warranty is concerned the trend in the field of quality and reliability is towards the more extended definitions of product quality [Ber 00], [Bro 98].
Without an excellent knowledge about the quality of the products, warranty claims might be much higher than expected [Bli 96]

7. Timely field feedback availability
With the increase in the speed of development less information on (causes of) field reliability of products is known in product development. The information that becomes available on quality and reliability will relate to increasing older (and thus less relevant) generations of products [Pet 03].



	1989	1999
Warrantee period	6 month – 1 year	3 years
Failures covered	Material defects	Any customer complaints
First line support	Dealer/service organisation	Helpdesks (free phone number)
Logistics	Via service centre 3 years	Replacement at home

Figure 1-2: Percentage no fault found in modern high-volume consumer electronics [Bro 04]

8. Time to full production ramp up
Rapid product lifecycles and high development costs pressure manufacturing firms to cut the time to reach full capacity utilization (time-to-volume). The period between completion of development and full capacity utilization is known as production ramp-up. During that time, the new production process is ill understood, which causes low yields and low production rates [Ter 98].

2.2 Impact of the trends on companies

To adapt to the changing environment as described by these trends companies are forced to be time- and cost- driven on one hand, while dealing with growing product complexity and assuring quality and reliability levels on the other hand.
In other words: more complex and more reliable products have to be developed, produced and delivered faster with less knowledge on what is happening in the field [Smi 03]. These trends are therefore causing a constant conflict [Mol02].
The mentioned trends have led to difficulties for companies in satisfying the customers' needs and expectations.
The increasing customer demands force companies to compromise between functionality, quality and reliability of the product that results in non-full coverage of the customer requirements and expectations.

The existing methods in new product development, production/supply processes are apparently not able to deliver a product that fully meets the customer's requirements and expectations.

As described the time to learn (fully adopt) the customers' needs, expectations and grievances (complaints) is too long compared with the development time of a product. The speed to bring new products to the market has increased considerably, where the feedback time to learn from a product has not been improved at the same speed.

The faster actual product feedback is available the sooner product changes can be made according to this information [Rob 06]. However, when product performance feedback takes too long compared to the development time, these product changes can only be made long after product launch.

This has brought difficulties for companies in producing products meeting the customer and company requirements.

Hypothesis I:
There are several trends in consumer electronics industries leading to a growing number of products that are not satisfying the customer needs and expectations and lead to an increase in customer complaints.

The next chapter describes how this hypothesis is translated to a case study at a large Lighting electronics organization.

Chapter 3 The hypothesis and research approach

In this chapter the hypothesis of chapter 2.2 is examined in order to be rewritten (paragraph 3.1). Paragraph 3.2 introduces the case study company. In Paragraph 3.3 the research approach is described.

3.1 First hypothesis description

Several investigations and case studies to analyze a number of the trends and to find approaches to deal with these trends, have been done in the consumer electronics industry (e.g. [Pet 03], [Oud 06]).
The consumer electronics industry typically is a retail industry. Retail can be characterized as the sale of commodities or goods in small quantities to end customers [Web 71]. In the value chain the retail business is preceded by business-to-business sales (B2B). Business-to-Business is the exchange of products, services, or information between businesses rather than between businesses and consumers.

The new hypothesis now is updated for inclusion of the business-to-business environment.

Hypothesis 1.1:
In a business-to-business as well as retail environment an increase in customer complaints is found. This is caused by several trends leading to a growing number of products that are not satisfying the customer needs and expectations.

The main focus is therefore on a field study into a business-to-business environment.

3.2 Introduction of a case study

A Business Unit (BU) of a large world wide operating lighting electronics company observed an increase in its warranty costs over the past years.
This business unit typically operates in the business-to-business environment and could serve as a case study for the hypothesis 1.1.

The hypothesis is narrowed down to a lighting electronics business-to-business organization.

Hypothesis 1.2:
In a lighting electronics business-to-business environment as well as consumer electronics retail environment an increase in customer complaints is found. This is caused by several trends leading to a growing number of products that are not satisfying the customer needs and expectations.

3.3 Research approach

First step is to have interviews with the case study representatives to retrieve background information that will be used to further refine the hypothesis.

As a second step a literature survey will be conducted to find possible, theoretical causes for the situation as described in the hypothesis.

After that, the third step entails setting up and conducting the practical case study via research questions to support the theoretical background.

Finally via synthesis conclusions and recommendations will be drafted entailing:

- General conclusions for the total research;
- General recommendations;
- Recommendations for further research

Chapter 4 Interview information

The researcher interviewed several people at the case study organization in order to get a first insight into

- the organizational set up (see results in annex I);
- the processes affecting the complaints and warranty costs (see high level model in chapter 4.1.2);
- the way field information is used within the organization (see chapter 4.1.2)
- possible main causes for the increase in warranty costs (see Ishikawa in chapter 4.1.3)

Annex II contains a table with the names of the people interviewed as well as their function within the case study.

4.1 Interview results

4.1.1 Warranty costs

The case studies' mother organization pays out more than $XY Million per month on warranty costs worldwide. The trend is increasing. More than 90% of these warranty costs are reported in the case study.

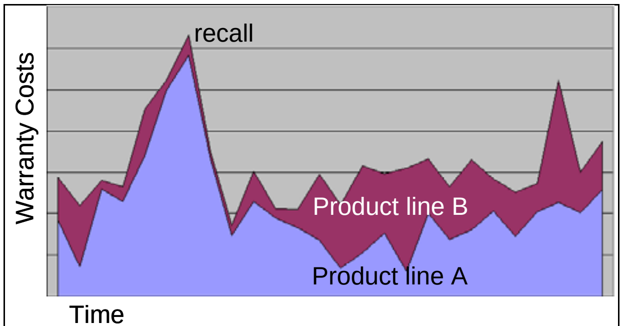


Figure 4-1: Warranty costs paid

4.1.2 Developments in the Business Unit

The interviews gave insight into a few possible developments in the field.

1) Each field quality incident is solved. A "pipeline effect" is observed: there is a lag in the impact on warranty. Management cannot see the benefits so far in the results trend and is unable to forecast when benefits will show.

2) There is concern that payments under "commercial considerations" do not happen in a controlled way.

3) Management is not sure that engineering changes to solve specific problems are used as learning opportunities and copied into running products and future designs.

4.1.3 A first model

The information taken from the interviews is processed into a high-level process map (a process map is a graphical representation of a process) covering those processes that affect the warranty costs.

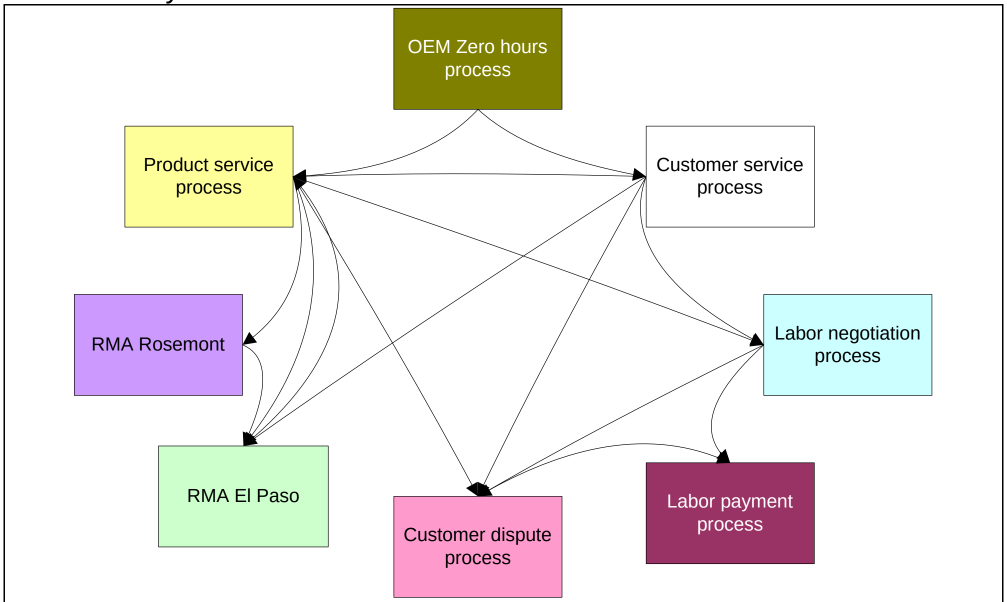


Figure 4-2: High level case study process map

4.1.4 High level cause and effect

A high level cause and effect diagram is created which identifies possible causes for the increase in warranty costs as according to the interviewees.
A cause and effect, or Ishikawa diagram, can be used to structure a brainstorming session. It immediately sorts ideas into useful categories and is used when identifying possible causes for a problem [Tag 04]

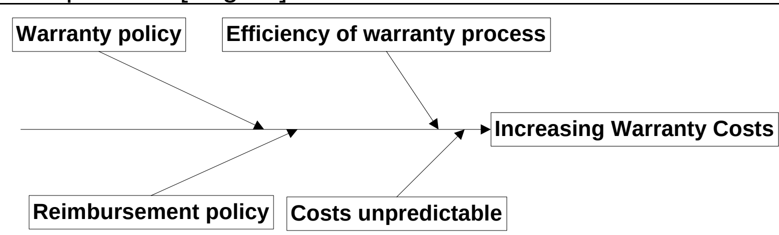


Figure 4-3: High level case study Ishikawa

4.2 Final research hypothesis

The interview results as described in the previous paragraphs gave reason for a refinement of hypothesis 1.2 into a final research hypothesis:

Research hypothesis: In a lighting electronics business-to-business environment as well as consumer electronics retail environment an increase in customer complaints is found.
This is caused by several trends leading to a growing number of products that are not satisfying the customer needs and expectations.
The absence of a well functioning field feedback system to learn from customer experience and behavior further amplifies this increase.

The learning from literature research into trends and the interviews in the field research both act as the basis for the hypothesis. This hypothesis gives room for building a theoretical framework based on three pillars:

1. Complaint management;
2. Failure classification;
3. Field feedback

The scope of this thesis is defined on technical product quality complaints coming back from outside the company. As such the researcher did not focus on design/ technical quality improvements, manufacturing process improvements or supplier quality improvements. In the picture below the scope of the thesis can be envisioned by the dotted arrows and the solid one from the customer to the after sales block.

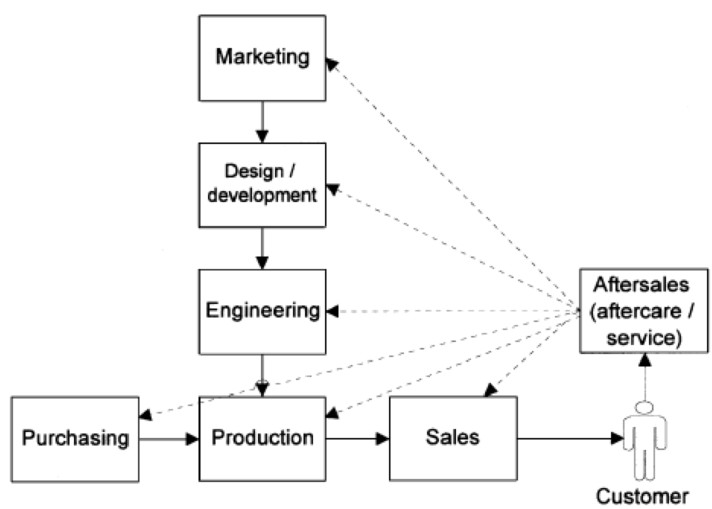


Figure 4-4: Information flow in a product creation process [Mol 02]

Chapter 5 Theoretical framework

Chapter 2 describes, via the identification of trends in literature and in industry, why the number of customer complaints on product quality are rising in the consumer electronics industry.
The literature covering these trends points out to some main areas for attention in order to manage and learn from these complaints. In general three areas are to be addressed:

1) complaint handling and management;
2) first diagnosis and categorization;
3) learn from field feedback

In this chapter the results of a literature study into field feedback and categories of faults are presented.

5.1 Introduction

In order to keep improving growth and profitability customers need to be retained and new ones must be attracted [Liu 01].

Gronroos [Gro 84] defines perceived quality as the gap between expected and experienced quality. Consumers complain whenever they feel that a product is not performing as expected [Mar 95]. According to Adamson [Adam 93] most companies spend 95 percent of their complaint management resources for reacting to individual complaints and less than 5 percent to analyze and use these as a means for improvement. Complaint management as a defensive marketing strategy could reduce total marketing expenditure costs [For 87]. Dutka [Dut 1994] and Konda [Kon 1993] argue that companies should be aware of dissatisfied customers even in case the number of complaints is not a good dissatisfaction index.

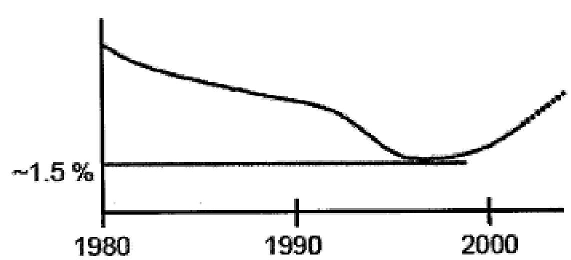


Figure 5-1: Percentage of customers complaining about new products [Oud 05]

In the past research in quality and reliability was focused on analyzing hard (out of specification) failures. The number of quality and reliability problems was decreasing. According to Den Ouden [Oud 06] the last decade the number of complaints on new products is rising again.

All arguments to opt for a means of retrieving customer feedback from the field, changes in the market make it necessary for companies to develop strong feedback systems. With these feedback systems companies can learn from the failure information and improve their product creation processes for future products [Sand 99]. The information that might be useful for the new product development is field feedback or customer product use data.

5.2.1 Complaint handling

A complaint gathering process should revolve around customers and continuous process improvement. It should be anchored with reliable data, support on-going communication with customers (including employees), be simple, and as easy to use as possible [Imd 97]. A reliable complaint gathering process provides the opportunity to enhance customer satisfaction and increase revenues by retaining existing customers, gaining new business through referrals and expanding market share.

While customer feedback is available in many forms, complaints are the most useful source of meaningful information to a business.

Complaints include product and service deficiencies, requests for rework, and goods that are returned. The only time a customer's complaint is destructive to business is when it is unknown to the supplier. This can be the result of customers themselves not sharing their dissatisfaction, or the supplier not hearing the complaints. Without this form of customer feedback, the supplier is unaware of product or service deficiencies and the supplier's revenues are potentially impacted.

One way in which customers can be encouraged to complain is to install a complaint gathering process that makes it easy for them to provide feedback. Successful complaint gathering processes provide for: 1. mechanized data collection, 2. quick fixes that respond immediately to the customer's complaint, and 3. the long-term elimination of the problem via process improvement [Sane 93].

In an ideal situation, a customer's evaluation of a supplier's products and services will be a component of ongoing feedback between the customer and supplier. However, customer feedback is often sporadic, and unless we are prepared to capture the data, it can be difficult to analyze. Feedback is often very positive or very negative. It can be delivered to anyone throughout the organizational hierarchy, from the Chief Executive Officer to the employee.

Data collection is crucial. The collecting and cataloguing of complaints is crucial to a successful complaint gathering process.

Regardless of the mechanism used to capture complaint data, it is important to mechanize the cataloguing of complaints to facilitate problem identification and root cause analysis. Key descriptors should be used to sort and analyze the complaint to determine if the problem is a random, on time event, or a systemic problem.

The value in beginning to collect data on complaints is that it helps the business to identify problem areas that should be better understood for immediate fixes and long-term process changes.

Successful complaint gathering processes provide for:

- Mechanized data collection
- Quick fixes that respond immediately to the customer's complaint
- The long-term elimination of the problem via process improvement

In determining the metrics that will guide data collection, a supplier might be tempted to try to collect too much data. In the beginning, start small, work with customers to identify major areas, evaluate the usefulness of the data being collected, and revise as needed. Complaints can evolve to process improvements-An effective complaint gathering process will include sub processes that [Imd 97]:

- Obtain complaints regularly;
- Acknowledge receipt of complaints;
- Resolve immediate problems;
- Provide data to improve processes.

5.2.2 Complaint management

Although important research has been conducted around Customer Complaints Management Systems (CCMS), most models are not comprehensive enough [Gon 05]. A model for CCMS was developed that integrates practice tested methodologies such as Total Quality management (TQM). Based on the Deming cycle [Dem 86] these steps are [Gon 05]

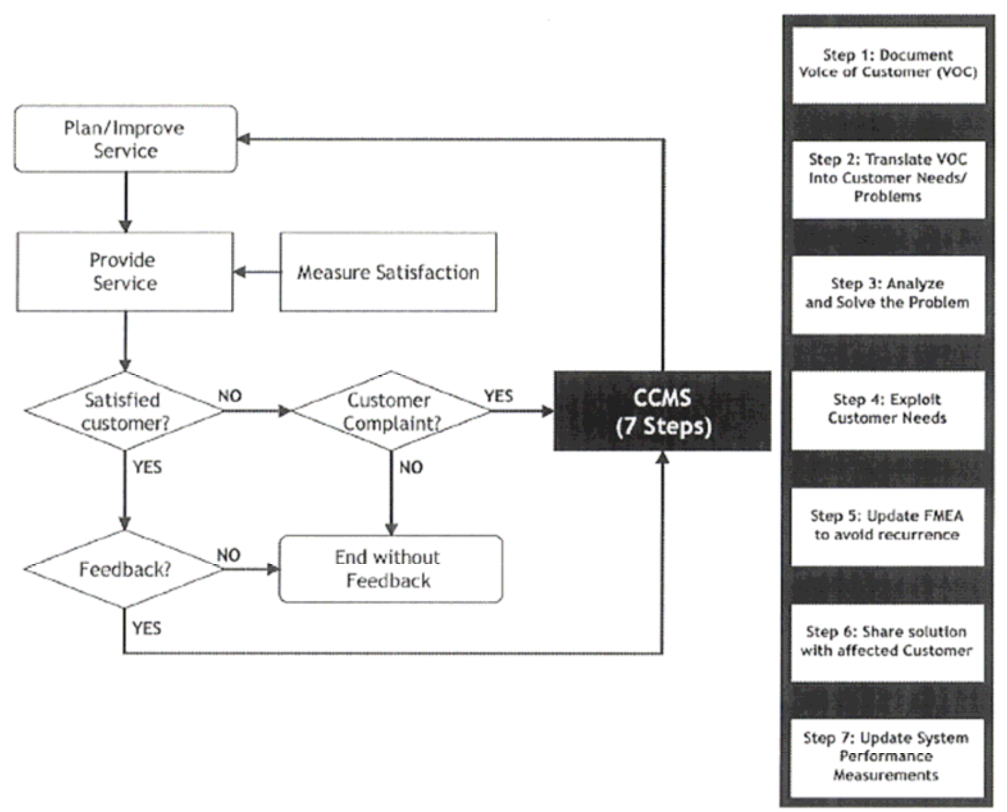


Figure 5-2: Customers Complaints Management System

Reflecting this model to practice evolves into the next 5 recommendations:

1.) Make a commitment. Collecting complaints is only the beginning. There must be a commitment from the management not only to the process, but also to making any necessary changes in the organization or the products and services. The commitment of the staff is also crucial, as it is often the front-line staff who is the recipient of complaints and the rest of the staff who are expected to implement any changes which are required. Their commitment and co-operation are essential.

2.) Create a formal process. Customers will be encouraged to complain if they see there is a formal structure in place for dealing with their complaints. The process should be:

- Designed by a small, cross-functional and multilevel group which represents all those involved including the customers
- Easy to use

In the beginning, it may be as well to limit the remit of the complaints process, so that the amount of data collected is manageable. Starting with product/service quality, cost and scheduling measures will give focus to the process without overwhelming the organization.

3.) Deal with the complaint. Not all complaints are the fault of the company. In fact many complaints are due to the incorrect use of a product or service by the customer. However, unless customers can communicate with the company they will remain dissatisfied, regardless of whether the product or service is at fault or not [Har 99].

Responsiveness is critical to the success of any customer complaints procedure. Having to wait for a complaint to be dealt with will do nothing to improve the customer's view of the company. That is not to say that the solution is easily available, it may not be, but the customer has to be made to feel that his or her complaint is receiving attention.

4.) Collect and analyze meaningful data. Each company's needs will be different, but common to all is the need to collect and analyze meaningful data. This may mean issuing questionnaires to customers on receipt of the product or service, setting up a toll-free telephone service or employing customer-service representatives. Selecting the most appropriate method of encouraging complaints is one of the responsibilities of the design team.- On a large-scale drawing of a product the number of complaints concerning a particular part can be plotted, highlighting exactly where the problems are arising

On a detailed flowchart the breakdowns or delays in service can be flagged at exactly the point where they occur.

5.) Develop the process. Typically an organization committed to improving its relationship with customers will first seek to deal with dissatisfied customers, but will soon realize that prevention is better than cure.

Such an organization will then use it's complaints procedure and the data it provides to try to solve problems before they occur, analyzing its processes to see where improvements can be made. The customer complaints process can be a powerful vehicle for cultural change if used properly and its impact on staff can be felt at all levels of an organization:

- Senior managers must be committed to the process and see it as a valuable customer service. Making someone responsible for the process who is trusted by both customers and employees, thus giving the process the necessary authority, both in the short and longer term.

- Middle managers, as the conduit of information from senior management to the employees, set the tone, pace and timing of the complaints process. Their day-to-day example of commitment to the process will do much to influence their staff.

- The staff are often the people who deal with the customers directly or are called on to implement any changes arising from the complaints process. Therefore their enthusiasm and commitment is of paramount importance.

5.3 Routes of dissatisfaction feedback

Hirschman [Hir 70] pictures a customer dissatisfaction feedback system that can serve as the basis for processes that make it possible to transform complaints from the user into information and knowledge for developers.

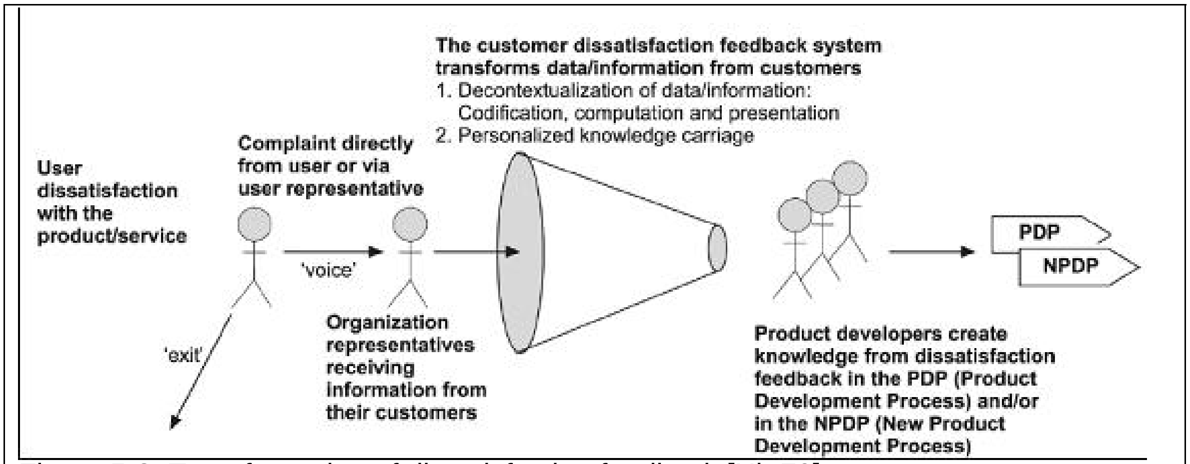


Figure 5-3: Transformation of dissatisfaction feedback [Hir 70]

Fundin et al [Fun 05] describe 9 routes for dissatisfaction feedback (call centre, internet, conventions, complaint systems, e-mail from service personnel, early warning systems, experiments, visits to users by developers, service personnel as knowledge carriers) which are categorized in four main constructs:

- Active and codified: the product development organization actively takes responsibility to collect information about user complaints by using well-structured methodologies.
- Active and personalized: the product development organization actively takes responsibility to collect information about user complaints by letting people from the product development organization or its network personally meets users.
- Passive and codified: the user needs to initiate the contact and inform about a complaint. The infrastructure for transforming the information from the user is organized through codification.
- Passive and personalized: the user needs to initiate the contact and inform about a complaint. The infrastructure for transforming the information from the user is organized through personal relations with product developers or people within the network.

Companies using active dissatisfaction feedback systems either have difficulties in knowing who their users actually are, or they have only a few customers and geographical nearness.
Companies that rely on passive feedback systems commonly rely on their current service organizations. Relying upon service organizations can be unsafe, though.

There are numerous filters from the dissatisfied user, and both personalized and codified information may be biased. [Fun 05].

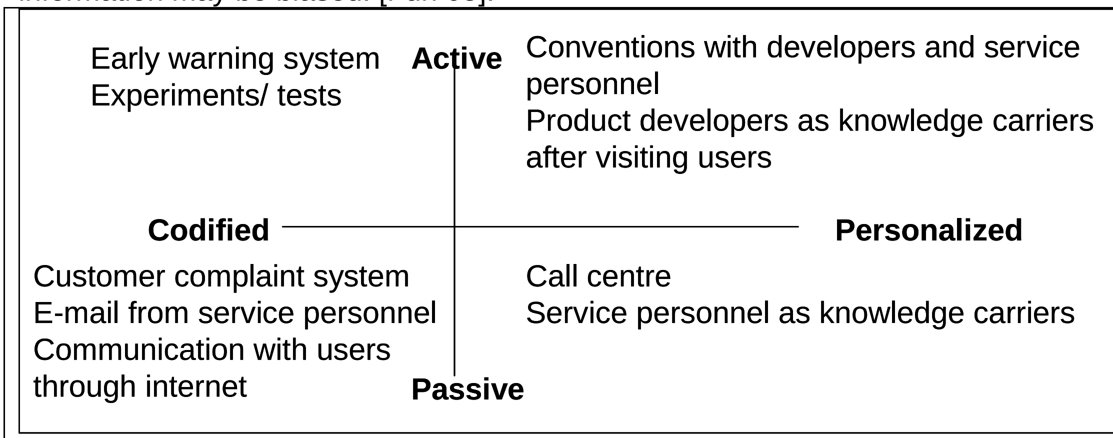


Figure 5-4: Main constructs for dissatisfaction feedback [Fun05]

Guthenke [Gut 99] state that for fast elimination of product faults generally 4 conclusions are valid:
1.) Collecting Field data is an important basic prerequisite for a serial production manufacturer. Data collection must be as extensive as necessary (to meet requirements) and curtailed as much as possible (to minimize costs).
2.) Visual support helps employees comprehend problem situations.
3.) Organization of an improvement process is the duty of top management, a task which extends over the entire process chain.
4.) Improvements are put into practice quickly and thoroughly if a consistent controlling system is in place."

5.4 Failure classification models

From an academic point of view, a proper classification model is important for consistent use of terminology and precise reasoning of the different failure classes. From an industrial point of view, a better classification model provides more accurate and easier detection of soft failures [Koc 06].

Several studies concentrated on developing a classification model failure types. Below an overview of a number of these classifications is made to serve as a reference for the practical survey that is done by the authors of this thesis.

5.4.1 Soft & hard failures

Geudens [Geu 05] modelled the failure categories from an academic perspective based on a distinction in the nature of the failure (hard vs. soft).

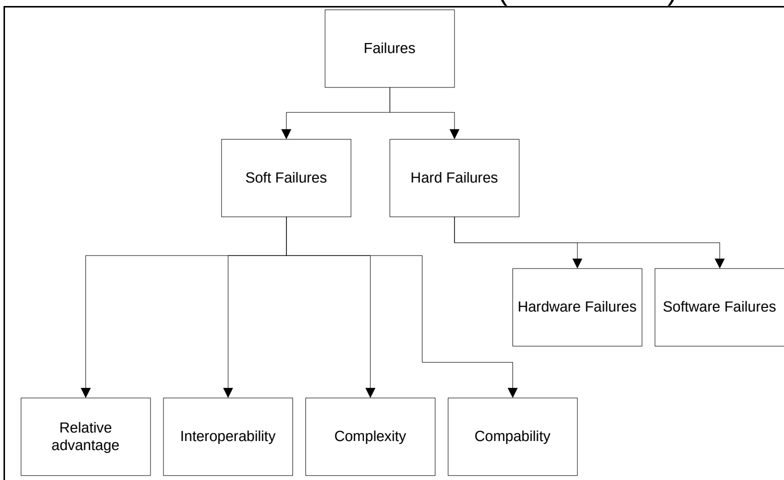


Figure 5-5: Failure categories from academic perspective [Geu05]

The model is created based on the fact that a failure does exist. This categorization model does not categorize failures with an unknown failure cause.

Koca et al. [Koc 06] define hard and soft failures as follows:

⇒ *Hard failures:* "In the universal set of all failures, hard failures are the ones where the product is incapable of performing part or all of its functions as listed in its specifications for an indefinite period of time without the intervention of technical support for recovery by means of repair/replacement of parts/missing parts supplement" [Koc 06].

⇒ *Soft failures:* "In the universal set of all failures, soft failures are the ones where the product, despite being capable of performing all of its functions as listed in its specifications, still necessitates professional (but not technical) intervention for recovery through instructions/information from an unexpected interaction state between the product and the user" [Koc 06].

Based on the product innovation characteristics by Rogers [Rog 03] the classification of soft failures in terms of *compatibility, complexity, relative advantage, trial ability* and *observables* is created.

According to Rogers certain customers adopt a new product more quickly than others. The product characteristics determine the rate of adoption. The soft failures are classified according to these product characteristics.

The product characteristics according to Rogers [Rog 03]:

- *Relative advantage:* the degree to which an innovation is perceived as being better than the idea it supersedes. The greater the relative advantage of an innovation, the quicker it will be adopted by customers.

- *Compatibility:* the degree to which an innovation is perceived as being consistent with the existing values, past experiences and the needs of the possible adopters. An innovation that is compatible to existing values, experiences or needs of a customer, is more likely to be quicker adopted.
- *Complexity:* the degree to which an innovation is perceived as difficult to understand and use. The higher the complexity, the lower the adoption rate of the customers will be.
- *Trial ability:* the degree an innovation may be experienced with on a limited basis. An innovation that is testable for a customer takes away uncertainty about the innovation and customers are more likely to adopt it quicker.
- *Observables:* the degree to which the results of an innovation are visible to others. An innovation is more likely to be adopted if the innovation is easier to visualize.

5.4.2 Product characteristics

Hovers reviewed the Geudens classification model and translated it into a two-category model [Hov 06]. Hovers' model concentrates on product characteristics that are used in classification model by Geudens. Hovers divided the product characteristics into the categories; product, process and an open box.

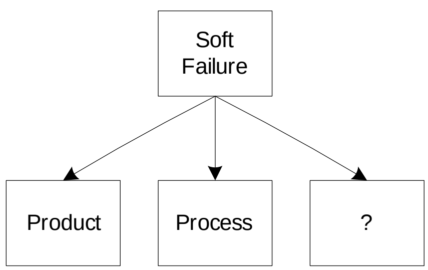


Figure 5-6: two category classification model [Hov06]

The latter category is one for those failures that cannot be classified in the other two categories. The category product relates to failures where the product is not meeting with the expectations of the customer.
The category process is related to failures where the customer experiences difficulties in using the product or experiences problems in the usage of the product.

5.4.3 Service perspective

Hartog [Har 06] classifies failure categories from the service perspective in the industry.

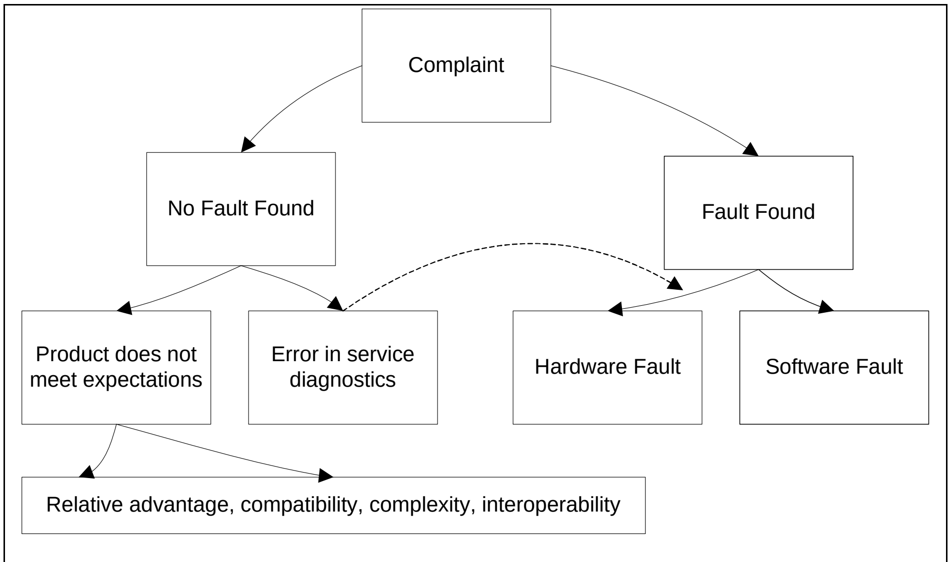


Figure 5-7: Failure categories from the service perspective [Har 06]

The model splits a complaint of a customer into product failures where the failure can be found (Fault Found) or no failure can be found (No fault Found). In the first case, the cause is either a fault in the hardware of the product or a fault in the software of the product. If the product failure cannot be identified (No Fault Found), this is because the service diagnosis was wrong or the product does not meet the product specifications. The error in the service diagnosis resulted in a wrong classification.

The actual failure, which was wrongly classified as a No Fault Found complaint, appeared to be either a fault in the hardware or in the software. In this model the No Fault Found and the Fault Found categories are therefore not completely exclusive.

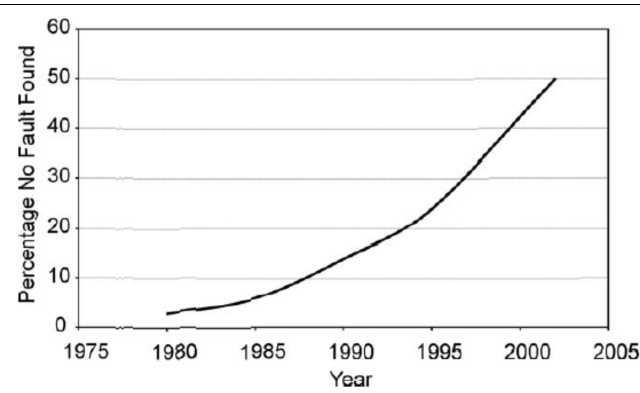


Figure 5-8: Percentage no fault found in modern high-volume consumer electronics [Bro 05]

Failures with an unknown cause are often seen as No Fault Found (NFF) or Fault Not Found (FNF). According to Brombacher [Bro 05] the percentage of these No Fault Found complaints in the consumer electronics industry has increased. In order to prevent and control these failures, more insight in these kinds of failures is necessary.

5.4.4 Fault Not Found failures in the aerospace industry

In the so-called Reliability Enhancement Methodology and Modeling for electronic equipment (REMM) Project [Jam 03], work programs are launched to investigate, understand and propose action, to reduce the occurrence of Fault Not Found failures in current product and new designs, throughout the Aerospace industry by:

1. Examination of Fault Not Found issues at a system level that can highlight common areas of concern for all partner companies and across the Aerospace industry.
2. Classification and Root Cause Analysis of service-data collected by partner companies.
3. System modeling the 'softer' Fault Not Found issues to determine the effects of intervention.

The REMM Project has developed a practically applicable failure classification for Fault Not Found failures in the aerospace industry.

The product removal classification flowchart that is used in the aerospace industry gives insight in the failure analysis in the aerospace industry.

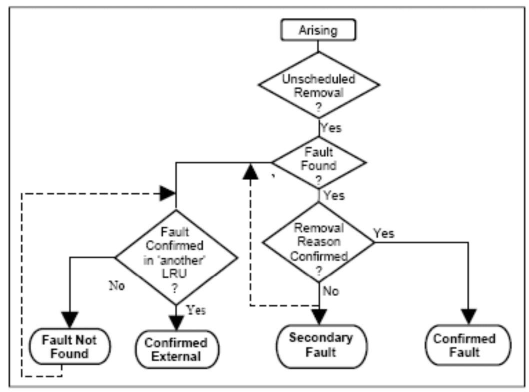


Figure 5-9: Fault analysis flowchart [Jam 03]

Way of working: After an unscheduled removal, either a fault is found or not. If the fault is found and the removal reason is confirmed via testing, the failure is classified as a confirmed fault. Whenever the fault is found but the removal reason is not confirmed via testing, the found failure is compared with other line replaceable units (LRU) and whenever the cause of the fault then can be found, the fault is classified as a confirmed external fault, indicating that the LRU itself was not causing the failure.

Whenever the fault still can't be found, it is classified as fault not found (FNF). Then a deeper root cause analysis is done to find the most significant reason behind the unscheduled removal till the fault can be confirmed external.

5.4.5 Analyzing failures

Geudens found that product reliability no longer is dominated by component failures [Mol 02&Geu 96]. This is caused by improvements in component reliability, lack of information deployment into the product creation process [Mol 02] and underlying business processes [Lu 02]. If companies want to solve reliability problems by a simple problem description combined with detailed knowledge about the product is this usually not sufficient. Often information about the environment in which the product was used and information about the way the product was used by the customer is also needed [Oud 05].

[Pet 03] describes that the most often used model on which reliability predictions are based is the so-called bathtub curve reliability model (see figure 5-10). This model is characterized by the existence of three phases that the products show with respect to reliability.

• Phase 1: early failures due to immature products / manufacturing processes
• Phase 2: mature products during useful life
• Phase 3: degraded products due to end-of-life wear out

Kim Wong observed that for electronic products the failure rate curve is better modeled by a four-phase roller coaster curve (figure 5-11) than by a three-phase bathtub curve [Pet 03] These phases entail:

1. ***Hidden 0-hour failures***: Sub-populations of products not meeting with customer requirements at t=0.
2. ***Early wear-out***: Sub-populations of products operating according to specifications but showing, either due to product tolerances and/or tolerances in customer use, deviating behaviour with respect to degradation.
3. ***Random failures***: Defects, induced by random events, either internally in the product or externally from customer use or other external influences.
4. ***Systematic wear-out***: Defects initiated by failure mechanisms in products that lead to systematic degradation of the main population as function of time and/or product use.

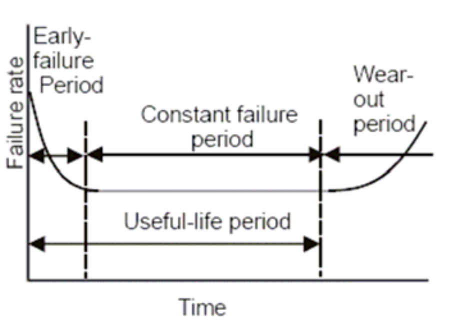


Figure 5-10 Bathtub curve [Pet 03]

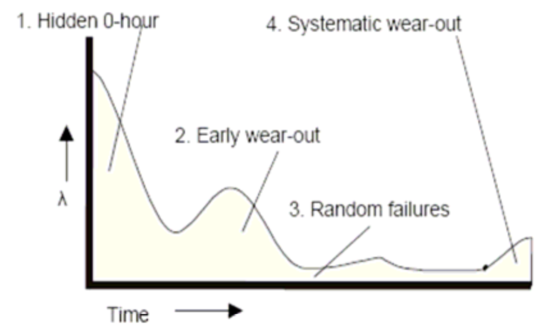


Figure 5-11: Rollercoaster curve [Pet 03]

5.5 Field feedback versus lifecycle phases

Field feedback is to be aimed at different places in the organization but primarily the development department has the proper equipment to process this information into improved or new product generations.

The product development process can be modeled in different ways. The product lifecycle model from Berden et al. [Ber 00] describes the different phases in product development:

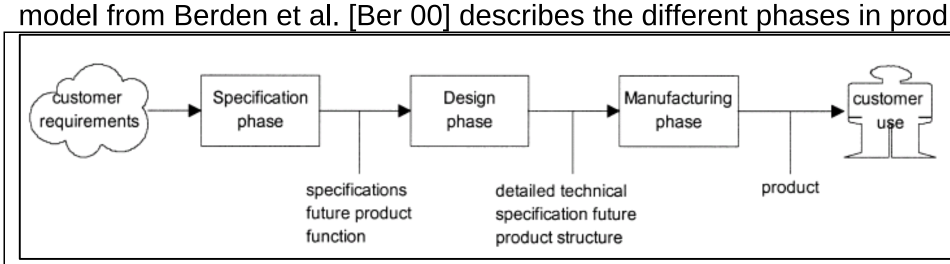


Figure 5-12: The product lifecycle phases in development [Ber00]

The development process starts with translating customer requirements into product specifications. This is represented by the specification phase. In the second phase, the design phase, the product specifications are transferred into detailed technical product specifications. These detailed technical specifications are later translated into the design of the product right before the manufacturing phase. Next the product is released for manufacturing. Finally the product is launched on the market, which is the end of product development.

The product is sold to the customer and the customer uses the product [Ber 00]. During all these phases, different departments of a company are involved with the development of a product.

5.5.1 The marketing perspective

Customers complain when they feel that their purchase is not performing as expected [Mar 95]. Consumer complaints may lead to the loss of existing customers and a damaged brand image. In order to remain competitive and deliver on profit promises companies have to attract new customers and keep their current customers to sell their products [Liu 01]. Therefore it is not only important for companies to prevent customer complaints, but also to respond effectively to their complaints.

Customer touch points
Input from the customers is not limited to the identification of the customer needs only. During the whole development phase and after that, contact with the customer has to be kept to verify and ensure that the product fulfils the customer’s needs. This can be done in several ways e.g. by bringing the customer into the process to view facets of the product as the prototype or final product takes shape. Waiting till the very end of the development phase to unveil the product to the customer can lead to a late identification of a customer needs versus product characteristics gap [Coo 94].

Another approach to involve the customer into new product development is User Centred Design (UCD). The approach requests attention for the customer requirements of the product at every stage of the product development process.
The main purpose of that process is translating identified customer requirements and expectations into product characteristics while a main customer is involved in a number of phases in the actual development/innovation process.

According to Rogers [Rog 03] a product's success will also depends on the type of customer it is sold to. In the Technology Adoption Life Cycle (TALC) model by Rogers [Rog 03] there are five different groups of customers distinguished; Innovators, Early Adopters, Early Majority, Late Majority and Laggards. A customer adopts each technologically new product with a different adoption rate.
Each of these customer groups responds differently to new high-tech products.

Den Ouden [Oud 06] describes not only the customer use process but also what areas of dissatisfaction can occur during the use of a product. This makes this model interesting for the analysis of failures. The following consumer process model with areas of dissatisfaction is described:

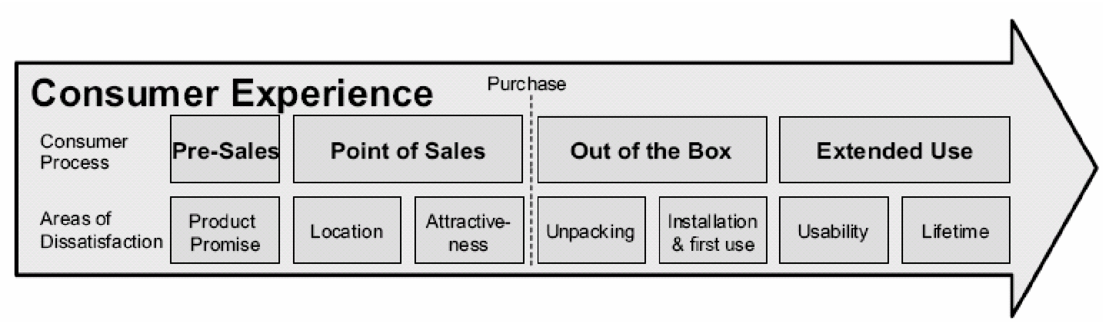


Figure 5-13:The consumer process and (potential) areas of dissatisfaction [Oud 06]

Pre-sales phase & point of sales phase are part of the purchasing process of a consumer.
The pre-sales phase starts with a customer that identifies a need or experiences a problem that needs to be tackled.
The out-of-the-box experience and the extended use phase are the usage phase. The customer installs the product. Next first usage takes place.
In the extended use phase the customer is experiencing the product usage.

Factors influencing the usability of the product:

- effectiveness (accomplishment of tasks in terms of speed and errors),
- flexibility (allowing adaptation to variations in tasks and environments),
- attitude (acceptable levels of human costs in terms of discomfort, frustration and personal effort)
- learn ability (time to learn and retention).

A customer complaint can be triggered at that moment where the customer experiences problems on one of the above areas or when the product does not fulfill the customer's expectations in these areas, [Oud 06].

Human Computer Interaction is a method to explore the ease of use of the functionality and features of a product. Especially the design of the user interface can be explored with Human Computer Interaction [Shn 05]. HCI is applicable to products containing software.

Within Philips the customer touch point wheel is introduced [VPH 06]. The wheel pictures different moments in customers' experiences with a company. Each of these moments carries its own "experience" and can result in complaints. This thesis focuses on the post purchasing experience of the wheel.

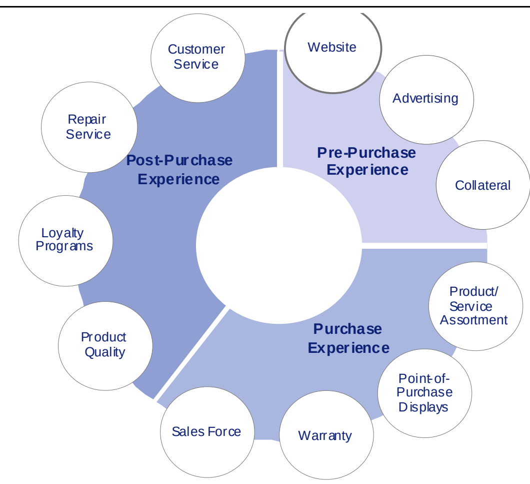


Figure 5-14: The Philips Customer Touch point Wheel [VPH 05]

5.5.2 The quality and reliability engineering perspective

Failure Mode and Effect Analysis (FMEA) [Crev 03] is a risk management tool that is widely used. FMEA examines potential failures in products or processes already during product development. FMEA helps to select remedial actions that reduce impacts of life-cycle risks on failures. This risk assessment is based on knowledge of previous products and technologies.

Design for Six Sigma [Crev 03] and Robust Design [Pha 89] are covering the whole development process. Aim is to design and optimize the design according to technical specifications and reduce variability on these specifications.

Accelerated testing to learn about a product's performance before its introduction on the market is increasing in usage. Accelerated testing makes it possible to shorten the test feedback time. Accelerated tests are suitable for shortening the feedback time to learn from a product. These tests are only successful in preventing hard failures. Several different accelerated tests are applied [Oud 06]:

HALT, Highly Accelerated Life Tests to find the limits of product technology in product design
HASS, Highly Accelerated Stress Screening used in production to find the weaker product
MEOST, Multiple Environment Over Stress Test increases a combination of stresses until a failure occurs
RMEOST Random Multiple Environment Over Stress Test uses a random combination of stresses to identify failures quicker

Lu et al. [Lu 00] proposed a strategy called stressor-susceptibility analysis. The stressor is the physical stress influencing the quality and reliability of the product and the susceptibility is the probability function indicating the probability that the product will fail after a certain time under a given set of stressors.

5.6. Field Feedback

A better feedback from the field is needed since the existing information feedback cycles are not effectively and efficient enough anymore [Pet 03]. Preventing soft failures needs more reliable field information and a better usage and quicker feedback of this information. Recent attempts have been done to improve the quality of this field information [Boe 04] and the feedback of field information [Boe 01].

Sources of information in consumer electronics:
- Service Centers (or Repair Centers);
- Helpdesks or Call Centers;
- Information from the Internet;
- Trade

These information sources provide the manufacturer information about the experiences of the customer with the product. This information has to be correctly filtered, translated, transformed and communicated through the whole company. The quality of the companies' information flows determines the quality of the information that reaches the product development department. Also, the trends in the consumer electronics industry have led to the change in the product creation process from solving problems whenever they appear to anticipating problems before they appear. For anticipating product problems, companies will need high quality information at the front-end of the product creation process. This information has to be deployed well through the organization, also in the interest of preventing soft failures in the future. However, information feedback loops do not always work in practice [Mol 02]. In his thesis Heynen [Hey 02] opts for regular customer – installer contacts where the installer takes the role of the organization itself.

5.6.1 Maturity index reliability

According to Sander&Brombacher [Sand 99] over the past decades large changes in quality and reliability management have been witnessed. Where in the 1950s/1960s the quality of a product depended on the quality of the components used; in the 1970s/1980s quality and reliability as functions of product structure and architecture was in the focal point. Since late 1980s/1990s the emphasis is on the relation between (quality of) business processes and quality of products (Total Quality Management and ISO-9000). The latter is worked out to show that the use of Reliability Information Flows can provide a maturity index for quality management [Sand99]

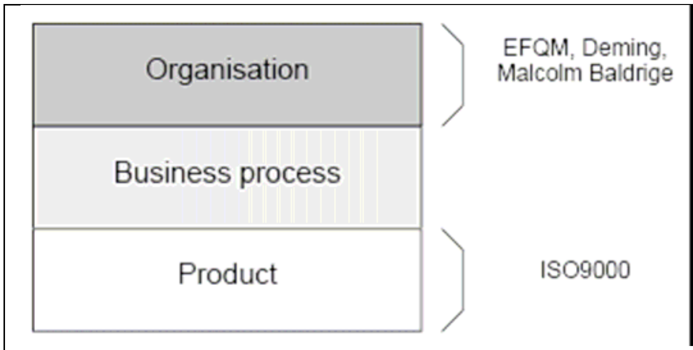


Figure 5-15: Different focuses for quality improvement [Sand99]

Organizations can focus their quality improvement efforts on several levels: Improvement of the products they create or on the quality of the business processes that generate these products, or they can focus on the organization as a whole, like is supported by award systems like European Foundation For Quality Management (EFQM) or Malcolm Baldridge. Award systems are focusing on organizational level improvement. This improvement is based on self-assessment and audit of the own organization and the environment the organization operates in. It demands to focus on internal and external stakeholders.

Nevertheless, in industry several examples show that certificates and awards are not a guarantee for excellent product quality/reliability [Sand 99]. Sander&Brombacher found several reasons for the disconnect between the above mentioned levels:

- Obtaining quality certificates and awards become an independent goal, not connected to actual business operation.
- Focus is mainly on nearby customers and not on the more remote customers (service helps the customer with a complaint, but it does not spend time in searching for the origin of the problem). This does not help two other customers of service, namely design and production.

- Companies are not sticking to the agreed procedure (e.g. under time pressure).
- Companies are confronted with fast-developing technology and shortened time to market requirements where a new generation of products is developed without knowing whether the quality of the present generation is satisfactory.

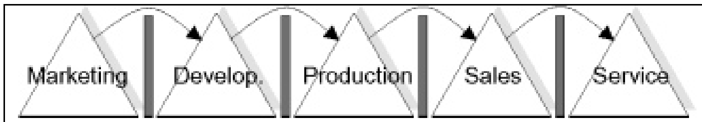


Figure 5-16: Sub optimization in a Taylor organization [Sand99]

Where an organization has organized itself according to a functional structure "a Taylor organization", it is almost impossible to collect and share vital information. The functional separation between the departments results in a strong focus on own, internal, performance and less on transfer of information from one department to another [Sand99].

Organizations operating modern product creation processes will need high-quality information in the front-end of the product creation process in order to enable early risk prediction. The organizations will also need good deployment of this information in order to introduce additional risks due to lack of communication [Sand99].
Sander and Brombacher introduced the Maturity index on Reliability (MIR), which allows the assessment of business processes on these aspects.
The MIR model assumes that a company is only able to take action if the relevant information on process output is available.

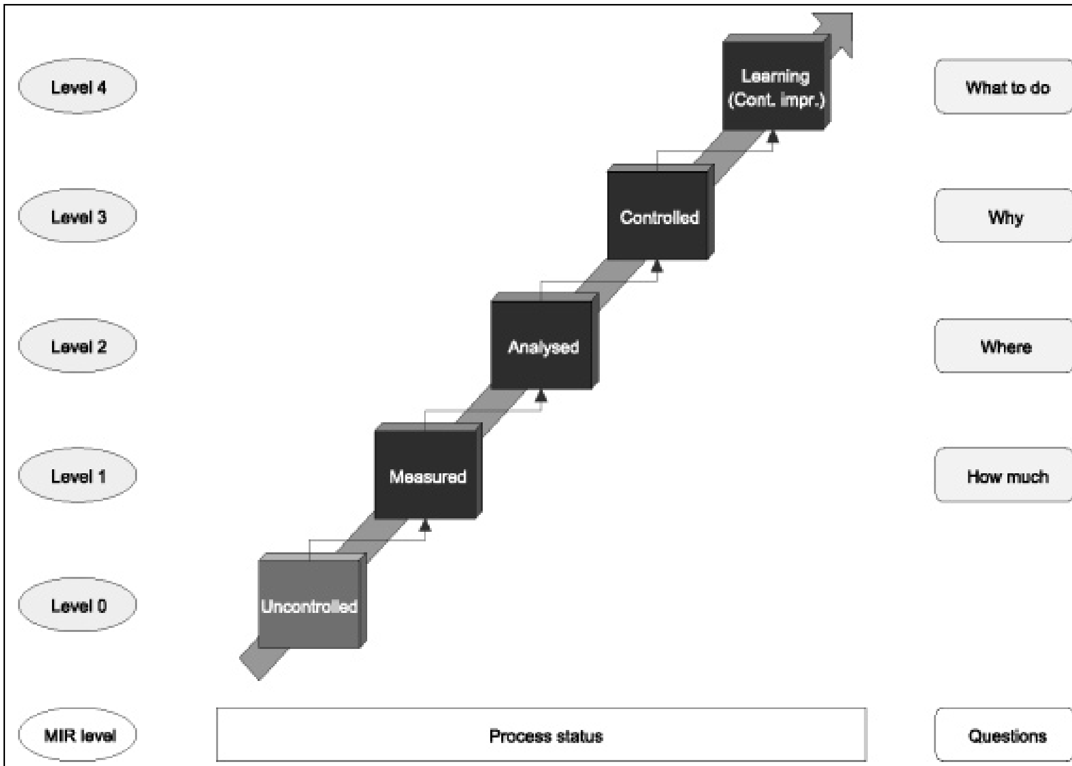


Figure 5-17: The MIR model [Sand99]

An explanation of these levels [Sand99]**:**

Level 0 The manufacturer has no relevant quantitative evidence of the process output (e.g. field behavior) of the products. Consequently, there are no control loops from service back to Production and Development. (Example: the number of service calls of a product is known but not in relation to the time of repair, the age of the product and the number of products sold.)

Level 1 The manufacturer has quantitative evidence of the process output of the products and the information is fed-back into the process, but the origin of the problems / deviations is unknown.

Level 2 The manufacturer has quantitative evidence of the process output, knows the origin of the problems (such as design, production, material or customer use), has the corresponding control loops, but does not know what actually causes the problems.

Level 3 The manufacturer has quantitative evidence of the field behavior, knows the origin of the problems and knows what actually causes them, and has the corresponding control loops and is able to solve problems. The manufacturer is, however, not able to prevent similar events from happening in the future again.

Level 4 The manufacturer has quantitative evidence of the field behavior, knows the origin of the problems, and knows what actually causes them and what to do about it. The level of knowledge is such that the manufacturer not only knows root causes of problems (technical and organizational) but is also able to anticipate and prevent similar problems in the future. All corresponding control loops are in function.

Petkova stated four critical remarks about the MIR principle [Pet 03]:

1. The MIR levels 1, 3 and 4 concern the number of failures, the root causes of the failures, and the elimination of the root causes. These aspects are relevant for all information flows. MIR level 2, however, concerns the location of the cause of the failure.
2. The MIR levels are presented as a hierarchical system on an ordinal scale, but in line with the aim of the MIR concept, the only structure is a classification.
3. In case studies not only information flows get a MIR level, but also organizations.
4. The MIR approach does not take into account the timeliness of the information. In time-driven development processes not only the information content and deployment is important but also the speed with which the information is gathered and deployed. The usability of information strongly depends on the moment at which the information is available.

Several case studies have shown the applicability of the MIR concept to determine if an organization and its business processes are able to provide high-quality information at the front-end of the product creation process in order to enable early risk prediction. Furthermore the MIR concept focuses on deployment of this information in order to introduce additional risks due to lack of communication [Sand 99].

Chapter 6 Field research set up

The research plan is set up by using the inputs from a literature study into trends influencing the number of complaints as described in chapter 2 and 3.3, by the inputs of the stakeholder interviews as collected in the ishikawa diagram in chapter 4.1.4 and by a literature study into complaint management; failure classification and field feedback.

6.1 Field research set up

Step 1: Reflect on the trends in literature and industry.
Step 2: Analyze the field feedback system by the following 5 questions. These questions follow the set up of similar analysis done by Petkova [Pet 03]:

1. Is there a product quality oriented field feedback loop?
2. If there is a field feedback loop: does it generate the required statistical and engineering information?
3. Is the collected field information suitable for quality and reliability improvement processes?
4. Is this field information analyzed correctly and in relation to the goal?
5. Is the information used for product quality improvement?

Step 3: Map the warranty process.
Step 4: Translate the input from step 1 and 2 into a Maturity Index Reliability representation of the warranty process.
Step 5: Collect the data as created in the warranty process.
Step 6: Analyze the data from step 4 to determine throughput times, payments, and analysis of findings.
Step 7: Analyze customer value surveys for customers' opinion on the warranty process.
Step 8: Create a detailed cause and effect diagram by interviewing stakeholders.
Step 9: Collect and compare warranty policies of competitors, suppliers and customers.
Step 10: Synthesize findings from steps 1-8 into learning and recommendations.

The last step is performed in chapter 8 under conclusions and recommendations.

Chapter 7 Field research

7.1 Reflection on the found trends for the case study

1. Globalization and price erosion
Where in the past lighting solutions were provided and supplied on a local-for-local basis, customers now more then ever can purchase their products from a globally operating industry. This led to continuous price erosion as a result of manufacturers driving to reach lower production costs and customers year over year demanding lower prices. As the figure 1 shows the case study company operates (manufactures) on a global base.

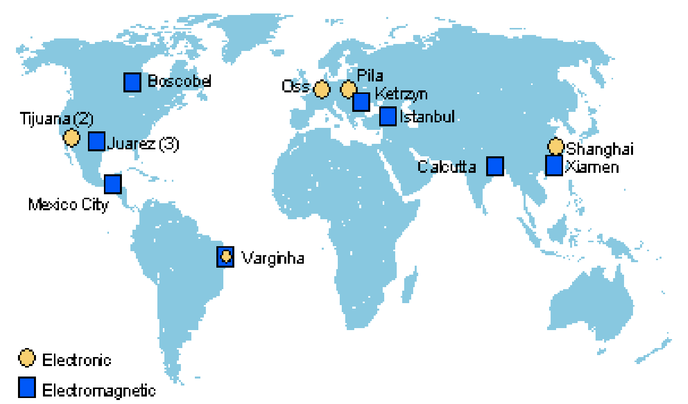


Figure 7-1: Global industrial operations

2. Outsourcing / sub contracting of activities
The company originally can be characterized as a vertically integrated company where traditionally all products were produced from components to end products. Now the production phases are decoupled and outsourcing of production activities as well as supply from low-wage, low-cost countries is a normal business. The components supply base is managed via globally operating commodity teams.

3. Speed of development
A decade ago the throughput time of a lighting electronics product took 2-3 years [Wij 06]. Now throughput times of 1-1.5 years are normal.

4. Increasing product functionality and complexity
The lighting electronics world is shifting from electrical to electronic products with an increasing number of software based functions. Traditional electromagnetic products serve the purpose of power regulators. For new lighting equipment and discharge lamps electronic products are equipped with a multitude of functions (e.g. dimming). Electromagnetic products have become real commodities. Electronic products managed to stay out of that less profitable area among other reasons because of this increased functionality. In 2001, the electronic product passed the magnetic one in total unit sales volume, the culmination of a trend that had been years in the making [DiL 03]. Electronic products, in fact, had already surpassed magnetic in dollar sales volume in 1995. According to the United States Economic Census, in 2002 electronic ballasts represented 57 percent of all lighting electronics shipped in the United States, and 69 percent of dollar value. Considering that electronic products comprised only 14 percent of units shipped and 34 percent of dollar volume in 1992, the rapid ascendance of this technology is quite remarkable. Going back a little further, to 1986, electronic ballasts barely even registered on the radar, representing just 0.6 percent of units shipped.

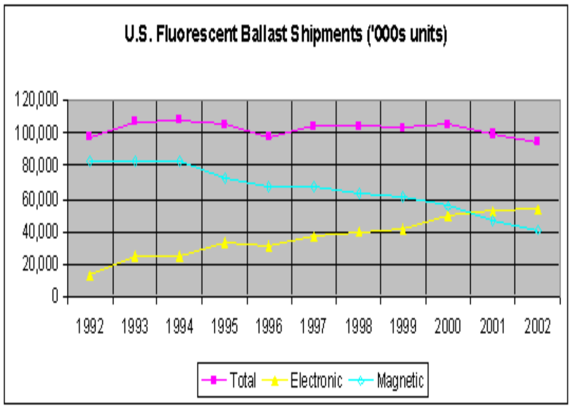


Figure 7-2: U.S. Fluorescent Ballast Shipments in Thousands of Units [DiL 03]

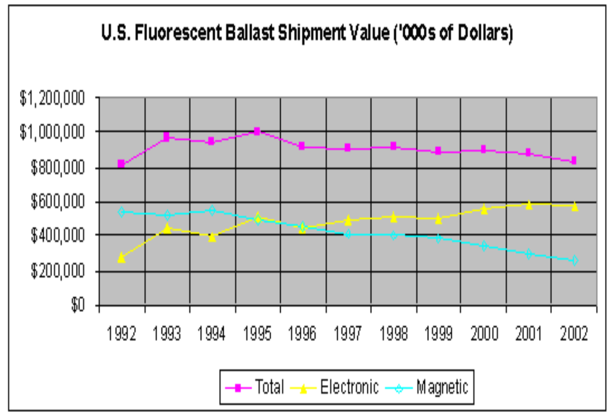


Figure 7-3: Value of U.S. Fluorescent Ballast Shipments in Thousands of Dollars [DiL 03]

The new product types now include software as a new technology component.

5. Changing Customer demands

Research shows that the use of dimming systems is steadily increasing, largely due to lighting industry participants specifying and recommending dimming systems to their clients primarily to provide the benefits of flexibility and energy savings in their projects. The research further suggests that dimming is being used in a broader range of spaces and applications, such as personal control and global control that includes integration with other building systems ... " [DiL 05a].

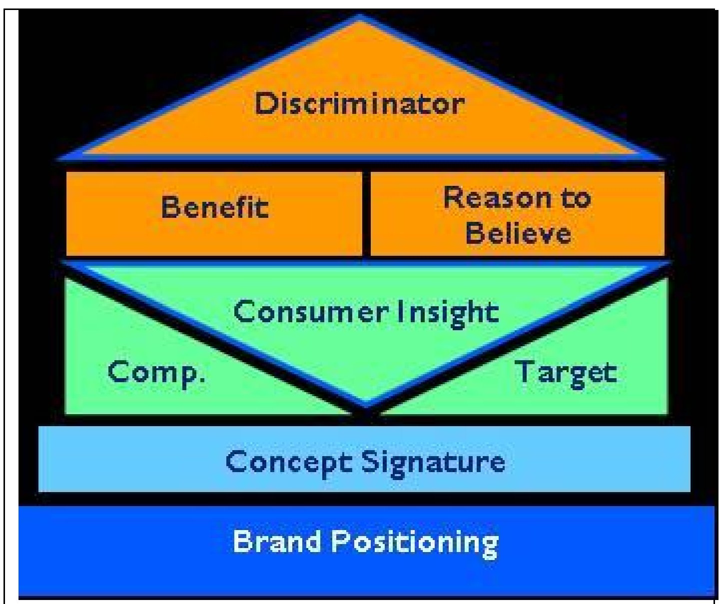


Figure 7-4: The Value Proposition House [Str 06]

In the product development process, the organizations' product management teams start by identifying the customer's requirements and translating these to a value proposition house. A Value Proposition House [Str 06] captures the bare essence of a positioning from the point of view of the end user (figure 7-4). It states what's in it for that end user, why the user would believe you and what makes the offering distinctive.

Capturing the requirements and expectations and translating these into specifications proves to be a difficult step. Whenever a company is facing difficulties in identifying these requirements, this translation and with that the final product is likely to be facing difficulties too [VPH 06].

6. Changes in (warranty) legislation and warranty terms

1) Changes in legislation

Effective April 1st, 2005, new Federally mandated ballast efficacy standards impact several magnetic ballasts. Specifically, these non-compliant ballasts cannot be:

Manufactured after April 1, 2005, sold to Original Equipment Manufacturers (OEMs) on or after July 1, 2005, sold by OEMs in fixtures on or after April 1, 2006, sold to distributors for replacement purposes on or after July 1st, 2010. A similar ruling and standards will also take effect in Canada. [DiL 05]

In Europe since 2005 energy efficiency requirements for ballasts for fluorescent lighting are set in European Union directives. [EU 00]

2) Warranty legislation

With the goal of strengthening the European Union's internal market, the European Commission approved legislation on May 25, 1999 that harmonizes the guarantees on consumer goods.The Product Warranty Directive, aims to protect consumers who make purchases outside of their Member State. The Directive sets up minimum standards for product warranties and mandates a warranty period of at least 2 years. Sellers whose products are found not to conform to the "contract" between the buyer and seller at the time the goods were delivered are required to replace or repair the nonconforming goods free of charge; reduce the price of the goods; or release the consumer from the "contract." [EU 99]

3) Warranty terms. A decade ago one ballast producer increased the warranty terms from 3 years cover to 5 years. Most producers followed. Now several producers increased warranty to cover not only the ballast but the lamp ballast combination and sometimes even the lighting system. A few large manufacturers are covering not only products but also labor in their warranty terms. In chapter 7.8 a model for warranty terms will be introduced.

7. Timely field feedback availability

In the lighting electronics industry, every 2-3 year a new generation of innovative products is created. Next paragraphs will focus on the timing when feedback comes available.

8. Time to full production ramp up

Interviews reveal that new products and new production lines are ramped up to speed in a short time period. Shorter than previous decades.

7.2 Field feedback system

ISO management systems (9000 for quality and 14001 for environmental mgt) are implemented at many organizations and likewise at the case study company.

Since mid nineties the company adopted the European Foundation for Quality Management model for business excellence and deployed it to all its businesses. The implementation resulted in an organization that no longer only focused on shareholder value but took a holistic view over all stakeholders. However, since the case study organization traditionally is managed the process way the European Foundation for Quality Management model driven holistic assessments could not ensure a well connected and merged product creation / market introduction and growth process. A typical way of picturing/model of the organization is shown below. Although the model resembles a Taylor structure (like figure 5-16), the approach behind that model was to emphasize interaction between several business processes.

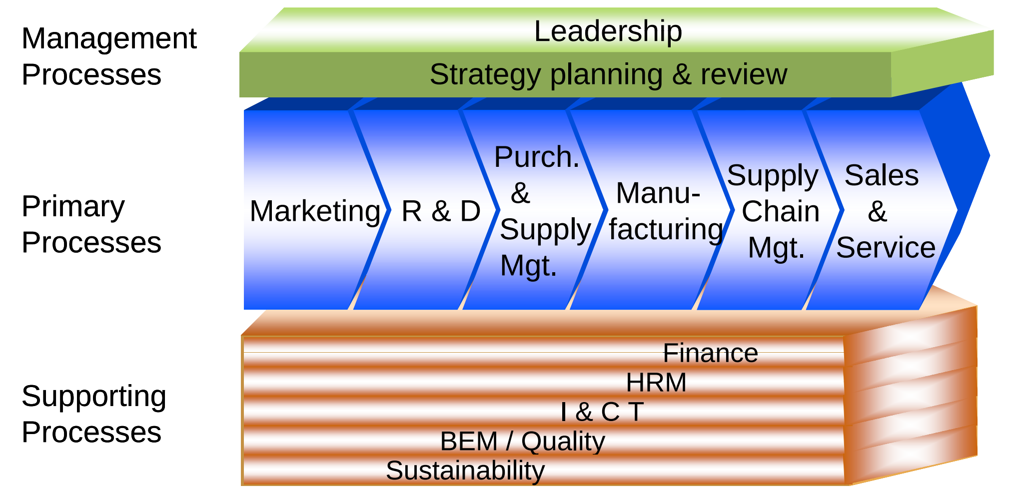


Figure 7-5: Business Process Architecture [Brow 06]

In chapter 4.1.3 a high level process map is defined. This map is used as the base model to do a deeper analysis of the actual feedback mechanisms in the company.

In her promotion thesis "an analysis of field feedback in consumer electronics industry" [Pet 03] Dr Petkova reported on her investigation into the structure, quality and speed of the field feedback flow of several consumer electronics companies. Her case study set up is the basis for the survey into the field feedback system of the company in this thesis.

- Is there a product quality oriented field feedback loop?
- If there is a field feedback loop: does it generate the required statistical and engineering information?
- Is the collected field information suitable for quality and reliability improvement processes?
- Is this field information analyzed correctly and in relation to the goal?
- Is the information used for product quality improvement?

The researcher also conducted a similar study into another Lighting electronics business unit in order to find similarities and differences. That business unit will be referred to as BU2.

7.2.1 Product quality oriented field feedback loop

The company installed a primary field feedback loop for all types of customers throughout the total value chain. Customers report back to the company via fax, e-mail, internet or a telephone hotline. The feedback is collected via a standard template (annex IV) that requests the product identification, customer identification and offers (limited) space to inform on reason for return. Focus of this primary feedback loop is on costs and fast material replacement and not on actual product quality or field information.
The second loop exists of the analysis of returned products. This secondary loop is created to determine the failure category.
The third loop is created to facilitate feedback on requested labor payments. This loop supplies some information to the company on the application in which the products are used.

The first loop is similar as found in the Petkova case studies as well as for BU2. In BU2 however the customer contacts are limited to those that are not filtered out by the value chain. At BU2 the % of claims/complaints reaching the organization therefore is lower.
Loop 2 and 3 are also found in BU2, the latter however is less frequently used.

7.2.2 Statistical and engineering information

The first loop delivers information on the number of returned products (and product types). Information on root causes is captured only in cases the hotline is used. The hotline operators extract as much as possible information on application and lighting system set up.
The second loop delivers statistical and engineering information on failure cause of the product. The product is sent back but not its total lighting system. Therefore the analysis can be referred to as a component analysis rather than a full system analysis. Actual accurate root causes therefore are not supplied.
The third loop delivers statistical information on where the most labor is paid. It hardly delivers any structured engineering information.

For the Petkova case studies statistical information is retracted but engineering information is limited.

In BU2 because of the fact that system complaints are dealt with early in the value chain it is impossible to get detailed and accurate statistical information. BU2 however is not interested in covering the total value chain with statistical information. From their experiences in the past they are able to predict the failure rate of their products quite accurately.
The product failure rate typically shows a “roller coaster curve” as shown in figure 5-11.
In order for the BU to get back more FF information a special project was started with one of their main OEM customers. This customer keeps track of all the failing products in their assembly lines. These failures are reported as zero hour failures to the BU.

7.2.3 Field information suitable for quality and reliability improvement processes

There are three main information loops and one smaller (but higher quality) loop recognized in the organization. These are pictured in annex V.
The first loop information can offer valuable information provided it is supplied rapidly after product launch. In most case however this loop does not bring much value to the quality and reliability improvement processes.
The second loop is used for input into the quality improvement process. It contains a second loop where the company has created a special taskforce that reviews failures that are never reported before and failures with new products. They use a “bulletin board” for monitoring progress. Open items are reviewed weekly with engineering, quality and product services.
The information exchange on the bulletin board allows for quick resolving of complaints and ensures feedback directly into the manufacturing organization. The design organization is not targeted directly by the bulletin board but is part of the weekly review meetings.
The organization is starting up specific actions to retrieve actual field application information.

The third loop does not deliver suitable field information into the quality and reliability processes. It mainly feeds the account and sales managers process.

Petkova's case studies show that some suitable data is delivered but its time lag makes the data available too late for the development processes.

In BU2 the situation is comparable to Petkovas case studies. Also here information is available at a rather late moment in time. However the BU2 has set up a close contact with one big OEM customer in order to get back all information on zero hour failures.

7.2.4 Information analysis in relation to the goal

Molenaar described three drivers for the after sales process: reduction of repair costs, reduction of unavailability of the product, development of products that better fit the customer need [Mol 02]. [Pet 03] translates this to 3 goals: costs, liability and customer satisfaction.
The goal of the company is twofold. First and foremost better control of the costs. And secondly liability by a timely availability of replacement products. The field feedback process is not equipped to serve the third goal of customer satisfaction.
BU2 aims at the development of products better fitting the needs of the customer and at costs.
In Petkovas research it proved that each of the companies in the study cases aims at a different prime objective.

7.2.5 Use for product quality improvement

The company especially uses the bulleting board and the analysis results for feedback into development, production and purchasing. The company does learn from the field feedback. Yet the learning for the biggest part comes from a component driven analysis rather then a system based one. Therefore the feedback of what is causing field problems is not retracted from the field.

7.3 Process mapping

This section describes the structure of the field feedback and decision-making process within the organization as well as the parties involved in this process.
The structure of the process is pictured on three levels. A high level model as shown in chapter 4.1.3 and further extended in 7.3.1; a more detailed model as shown in chapter 7.4 and the most detailed structure that is found in annex III.
There are different areas in the detailed process that are relevant to field feedback. These areas are highlighted previously in chapter 7.2 and subsequently 7.4.

7.3.1 Parties involved

The model in figure 7-7 shows the main parties involved in the process.
The process starts with customers. The customer either is an original equipment manufacturer, a wholesaler/ distributor, an installer/ service organization or an end-user.
The product services group, represented by the yellow block, plays a vital role in the process.
It takes care of warranty claims as well as technical calls from all customers. The customer service organization, the white block, processes calls from existing accounts only.

There is a special role for the quality assurance manager in the green block. He deals with the bigger accounts. There are two test facilities. One located at head quarters in Rosemont (lavender block) and one located in El Paso (light green block). The light blue, pink and purple blocks do not represent an actor or party. These represent a decision making process.

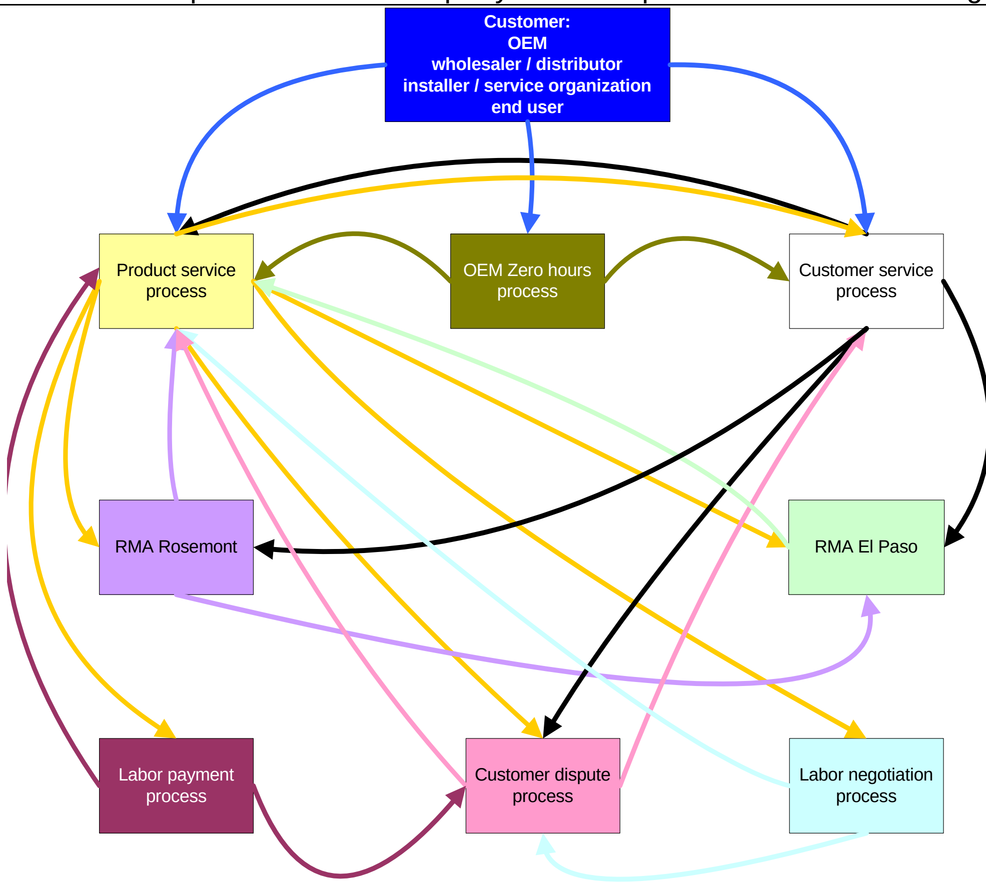


Figure 7-6: High level overview of field feedback and decision making process

7.3.2 Structure of the process

In this paragraph the processes within the blocks as well as the connections between the blocks will be outlined.

7.3.2.1 Customer

The customer (blue block) is the party that either:

Is a direct customer:

1.1 uses the lighting electronics in his own equipment (OEM customer);

1.2 buys the lighting electronics for resale (distributor/wholesale customer)

Or is an indirect customer:

2.1 an organization that installs lighting systems at an end user (installer);

2.2 an organization that maintains the lighting installation (service organization);

2.3 an organization / person that uses the lighting system (end-user).

All these “customers” can enter the process. All known accounts: OEM, distributor/wholesaler (customer type 1.1 and 1.2) via the customer service process. Some OEM customers use the OEM zero hours process as their entry. Installers, service organizations and end-users (customers 2.1,2.2 and 2.3) enter the process via the product service process.

The enterprise information system allows for 6 ways/reasons to enter material authorizations. These are listed in the table below.
The product service process uses codes 401 and 402. The customer service process uses codes 701-704.

Reason for order	Reason Description
401	Warranty Return: Other
402	Warranty Replacement: Other
701	Inoperable Return for Credit
702	Inoperable Return for Replacement
703	Inoperable Return Other
704	Quality Recall

Table 7-1: return reasons and codes

In practice a 2.3 customer most of the times enters the process via another customer (mostly 2.2 or 2.1). This has not been taken into a account for the modeling.
All customer claims and complaints are handled and processed.

7.3.2.2 Product service process

The product service process (yellow) can be split up into two sub processes:

a) Processing material complaints and claims from “not known accounts”.
b) Processing labor claims for all customers.

For both processes the organization creates a Return Authorization entry into the enterprise information system. The claim can now be traced via that number.

a) Via fax, telephone, internet or e-mail customer complaints and claims enter the process. The product service organization reviews the information via a non formal decision tree to determine if the claim is within warranty. Next the organization defines where the products need to be send to for further analysis. The customer sends the products free of charge to the Return Material Authorization organization for analysis. Customer receives a maximum number of replacement products.
After the Return Material Authorization organization analyzed the products and after decision for replacement took place, the product service organization will contact the customer for final arrangements.

b) In case a customer claims “labor” the product service organization starts a special labor negotiation process. “Labor” means the customer wants to be reimbursed for the hours and material he used to exchange the “faulty” products. “Material” would include the renting of scaffolds or elevators to reach and replace products.

The product service process gives input to:

- Return Material Authorization El Paso & EL Paso goods receiving, where material is received, classified and where standard analysis take place
- Return Material Authorization Rosemont, where special analysis takes place
- Customer service process, for feedback on test results
- Labor negotiation process, to determine if and how much “labor” will be paid
- Labor payment process, to decide on the final payments
- Customer dispute process, to escalate disputes with the customer

The process receives input from:

- Customers, on claims and complaints
- Return Material Authorization El Paso, on analysis results
- Return Material Authorization Rosemont, on analysis results
- Customer service process, for labor requests
- OEM zero hours process, for claims from the field
- Labor negotiation process, for decisions on payments
- Customer dispute process, for decisions on escalated disputes with the customer

7.3.2.3 Customer service process

The customer service process (white process) handles claims and complaints of existing accounts. It processes good unit returns as well as inoperable units.
Goods unit returns are those were the original shipment contained errors or where the customer made an order entry mistake. In some cases a good unit return is an excess of stock at the customer. The customer service process manages the flows of the good unit returns to the regional distribution centers. Where it is questionable if the products can be resold these are send to the Return Material Authorization El Paso organization.

Inoperable returns are only accepted if these are within warranty. As in the product service process also here, after some checks, it is decided where to test the product and how to inform the customer.
Any requests for labor are handed over to the product service process.

The organization creates a Return Authorization entry into the enterprise information system. The claim can now be traced via that number.

The customer service process gives input to:

- Return Material Authorization El Paso & EL Paso goods receiving, where material is received, classified and where standard analysis take place
- Return Material Authorization Rosemont, where special analysis takes place
- Product service process, for labor requests
- Customer dispute process, to escalate disputes with the customer

The process receives input from:

- Customers, on claims and complaints
- Product service process, for analysis results
- OEM zero hours process, for OEM issues
- Customer dispute process, for decisions on escalated disputes with the customer

7.3.2.4 OEM zero hours process

Some OEM customers have direct contact with the quality assurance manager (green process). He acts as a liaison between the customer or product service process and the customer to speed up resolving of the complaints/claims. The actual claim is handled via either one of the two processes but the quality assurance manager does the reporting. The quality assurance manager does not create the actual return authorization code.
Recently in this process a "pit crew" approach is launched. Via a pit crew people of different business processes are assembled to dive into a complaint and find ways to resolve it. The existence of the pit crew is so fresh that the results of its work are not yet available for further analysis.

The OEM zero hours process gives input to:

- Product service process, for labor requests and field issues
- Customer service process for other OEM issues

The process receives input from:

- Customers, on claims and complaints

7.3.2.5 Return Material Authorization Rosemont

Where claims involve a new design (younger than 1 year) or an unidentified problem in a mature product or a safety problem these are handled by the Rosemont Return Material Authorization (lavender process).
The Return Material Authorization employee receives the product, retrieves the claim information from the enterprise information system and designs a testing method. After testing he enters his findings back into the enterprise information system where it is picked up by customer service or product service.

The process gives input to:

- Product service process, for analysis results
- El Paso goods receiving process, for analysis that erroneously were sent to Rosemont

The process receives input from:

- Product service process, to perform analysis
- Customer service process, to perform analysis

7.3.2.6 Goods receiving and Return Material Authorization El Paso

All material analysis not handled by Rosemont are handled by El Paso.
The material is received and sifted by the goods receiving organization (orange process). An entry on the received number and type of products is made into the enterprise information system. The actual testing and analysis is done based on standard procedures by the Return Material Authorization organization (light green process). After testing findings are reported back into the enterprise information system where it is picked up by customer service or product service.

The process gives input to:

- Product service process, for analysis results

The process receives input from:

- Product service process, to perform analysis
- Customer service process, to perform analysis
- Return Material Authorization Rosemont, to perform analysis

Now that all involved parties and their internal links are described three main processes will be described.

7.3.2.7 Labor negotiation process

The labor negotiation process (light blue) has as a prime objective to ensure labor is only paid if certain conditions are met. The process is run by the product service organization. The company always tries to bring in an own contractor to do the actual job.
Were costs arise above a certain amount higher level managers are involved.
If the customer and the company come to an agreement the product service process takes over. In case the customer does not accept the proposal the case is escalated to the customer dispute process.

The process gives input to:

- Product service process, for further handling of agreed labor claims
- Customer dispute process, when customer and company cannot agree

The process receives input from:

- Product service process
- Customer service process

7.3.2.8 Customer dispute process

The customer dispute process (pink process) is managed by the sales organization. Sales contact the customer to try and resolve the issue within all fairness. If this is successful the product service organization takes over to handle the actual pay out.
If the dispute cannot be resolved the claim will be denied.
The customer dispute process handles labor claims as well as claims for products.

The process gives input to:

- Product service process, for further handling of agreed labor or material claims

The process receives input from:

- Product service process
- Customer service process
- Labor negotiation process
- Labor payment process

7.3.2.9 Labor payment process

The labor payment process (purple) is managed by the product service organization. It acts as the final step towards paying labor costs to the customer. Before doing so the process does a number of checks to find out how much costs were already made and should be deducted.

The process gives input to:

- Customer service process, where decisions are disputed by the customer

The process receives input from:

- Product service process

7.4 Maturity Index Reliability representation of the process

The information collected from within the organization is processed into a high level model (figure 7-7) as shown in chapter 7.3.1. Via interviews, data collection, taking part in processes, witnessing service calls, reviewing quality manuals and documents the high level model is refined into a detailed model covering all processes and sub processes affecting the claim handling process. This detailed model is included as annex III.
The model consists of 9 separate blocks as described under paragraph 7.3.
In the detailed model specific document blocks are added next to the processes. These blocks represent the enterprise information system. The blocks are linked to those steps in the sub processes where data is entered into the enterprise information system. Those places are of main importance when tracing and analyzing the information as referred to under paragraph 7.2. More specifically at those places where the maturity of the field feedback loops can be determined.

In paragraph 7.4.1 the steps to "translate" the detailed model into a MIR representation will be discussed. Next conclusions on the maturity of elements into the MIR model will be drawn.

7.4.1 MIR representation of the field feedback and decision making process

The Maturity Index on Reliability is developed to analyze the response of a business process to disturbances to be able to improve the business process. The MIR model assumes a company can only take action if the relevant information on process output is available [Sand 00].
In order to draw the MIR representation of the field feedback and decision-making process [Sand 99] proposes 5 steps:

1. create an activity model with all activities in the company that show relation to process output;
2. map and cross check communication between activities, remove off process activities;
3. identify information flows and loops;
4. establish MIR level in the information flows;
5. identify bottlenecks that are determining the current MIR level

The fifth step leads to the conclusions.

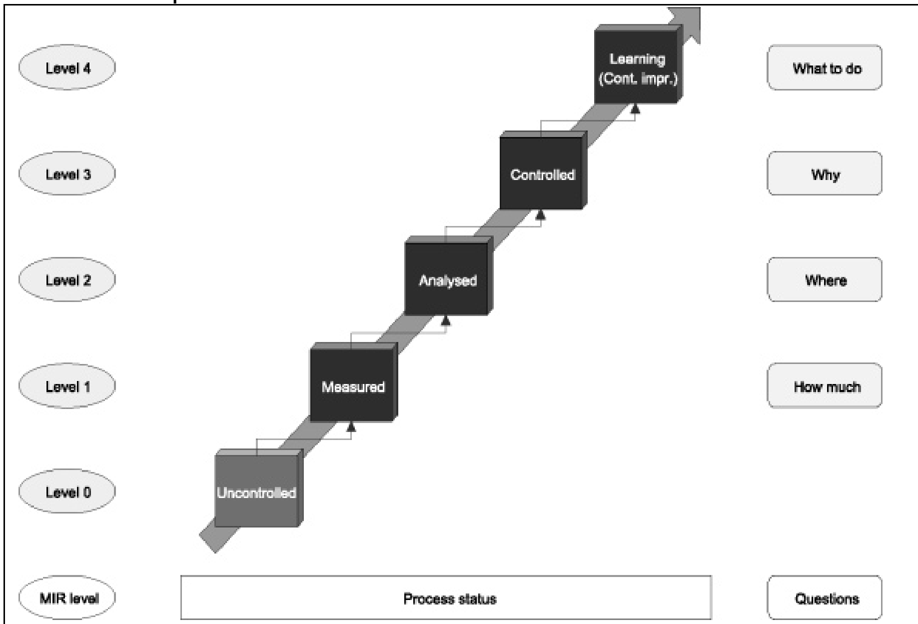


Figure 7-7: The MIR model [Sand 99]

Step1: a detailed model is created as found in annex III.
Step 2: all activities in the model are related to the process. Some are more directly or primarily related to information flow loops than others but still all play their role in the process towards process output.
Step 3: as described under chapter 7.2.1 there are three main information loops and a secondary one.
These loops are highlighted in the model in annex V.
Step 4: Loop 1: In the claim receiving and handling process the process output is measured (level 1) but actual root cause analysis does not take place. More than that, the process is not able to define what actors can solve the problem.
Loop 2: The material receiving and analysis process defines component causes for the field failure. The causes are related to supplier, design, manufacturing and in some cases to the application. This brings this process to a MIR level 2.
Loop 2a: The bulletin board information loop searches for causes, determines what actors need to be involved and is able to install corrective actions. In some cases also preventive actions are installed. The board is at MIR level 3
Loop 3: The payment decision and dispute process hardly measures indicators relevant to the full process. It does not reach MIR level 1, so it is on level 0.
Step 5: The second loop delivers a vast amount of analysis data. However actual field data, read application data, is not available many times.
The information loops are interconnected but apart from the bulletin board information exchange does not take place.

7.5 Data collection

The organization uses its enterprise information system (SAP) for complaint data entry and for monitoring of the field feedback and decision making process. The processes as described under paragraph 7.3 all have their data entries into SAP. All but the customer dispute process.

Several reports are created from the enterprise information system to inform management and customers.

After some interviews with the IT manager, the F&A manager and the Quality manager a long-list of attributes was created that could serve a purpose for hypothesis testing and for creating insight in basic data behind the MIR levels.

Account	Customer code	Distribution Channel	Period	Receive date (in the RDCs or test facilities)
Amount	Customer name	Division	Plant	RefDoc.No.
Can Code	Customer state	Document Number	PO	Requestor
Contractor/Esco	Date Code	Employee	Profit Center	return number
Cost Center	Date RA number send to customer	Product family	Pur Ord Type	Returns Analysis Tex
Create date (RA)	Date product tested	IBM code	Quantity	Sales doc. type
Created by	Date ra closed	Installation date	RA number	Sales Organization
Created on	Defect Category	Job City	Ra text	Shipping point
Customer	Defect Code	Job State for Contra	reason for order	Vendor
Customer address	Delivery date	Material	Reason for rejection	Warranty period

Table 7-2: attributes for further analysis

With as primary key the return authorization number several files were created from the enterprise information system.
In order to draw statically valid conclusions the files need to contain enough return authorization fields.

The basic files that were created:

	purpose	**start date**	**final date**	**RA fields**
1	Product analysis results	Oct-04	Apr-07	167908
2	Material costs	Jan-05	Mar-07	176786
3	Labor costs	Jan-05	Dec-06	14505

Table 7-3: basic files for data analysis

7.6 Data analysis

The enterprise information systems of the company provide a vast amount of data regarding the warranty complaints, labor claims and warranty processes. The model in annex III contains linkages between the processes and the enterprise information systems. Those linkages represent data flows into and from the processes. In this chapter those data are analyzed:

1) to find support for some of the identified trends;
2) to determine what field feedback actually is retrievable from current enterprise information systems;
3) to search for patterns in customer behaviour.

As a first step the data in the files was analyzed for anomalies.
Incomplete data and incorrect data (for example with dates after 2007) are removed.
As a second step a box plot and dot plot are made on the fields with costs and number of products returned for analysis.
A box plot shows [Bui 97], [Qsb 04]:

- The median
- The data range from minimum to maximum
- Outliers, which could be data errors or data points interesting for further investigation

Figure 7-8a:box plot labor costs

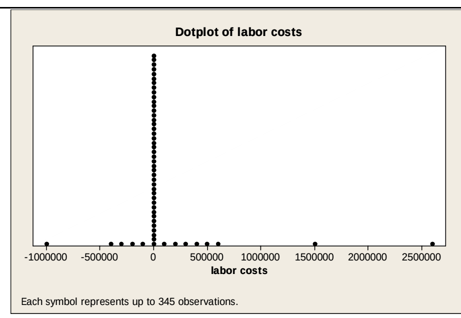


Figure 7-8b: dot plot labor costs

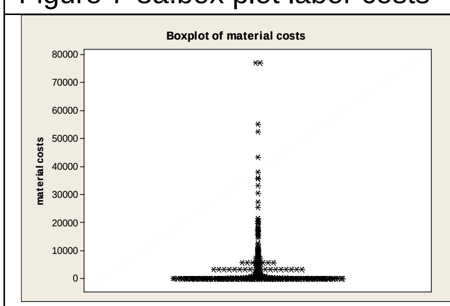


Figure 7-9a:box plot material costs

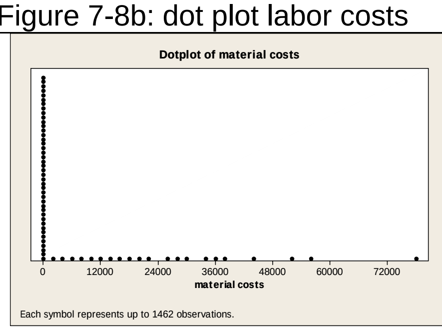


Figure 7-9b: dot plot material costs

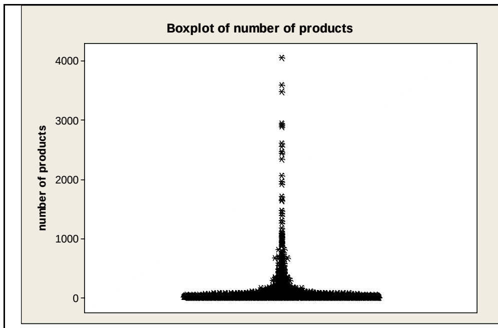


Figure 7-10a: box plot number of returned products in a batch

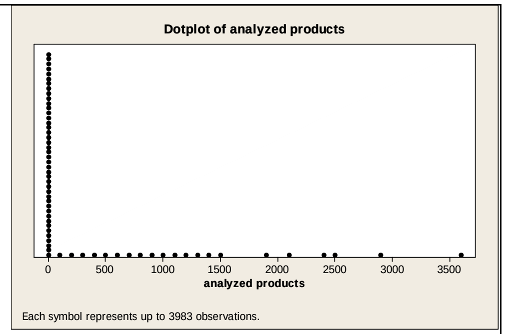


Figure 7-10b:dot plot number of returned products in a batch

The box plots showed some outliers that needed further investigation in order to ensure no erroneous data would affect analysis outcomes. More specific it shows at labor costs high negative and high positive data exists. The high positive numbers can be accounted for. The high negative numbers appeared to be existing accruals that in fact should not be reported under warranty costs. The data was removed from the database. It also proved that some payments were booked triple in the database (twice positive and once negative). Here it proved that these bookings were made twice to the customer and needed to be booked off the account again once. Also these double bookings were removed as to not interfere with the analysis outcomes.

At material costs several high value data entries appear. At number of analyzed products also a few high number data entries are found.

The data resulting from the above described filter steps is used as input for the analysis.

7.6.1 Analysis to find support for some of the identified trends

1) Changing customer demands

Customer demands change over time but can as well be different from region to region. The case study company has its base in North America. Its sister organizations are also region based (the other three main regions). In order to test regional differences the Field Failure Rate for the new (Electronic) products per region is calculated. It is shown in the chart below. Although each region runs the same product portfolio and is supplied by many the same suppliers, still regional differences are very clear between the Americas and Europe & Asia. Europe 1 and 2 are two different Business Lines. The data on the ppm scale is removed for confidentiality purposes. It is available to the graduation committee. The data can act as prove point for how a different customer demand/behaviour can result in different numbers of complaints and claims.
The American regions show significantly higher Field Failure Rates, although running the same product portfolio.

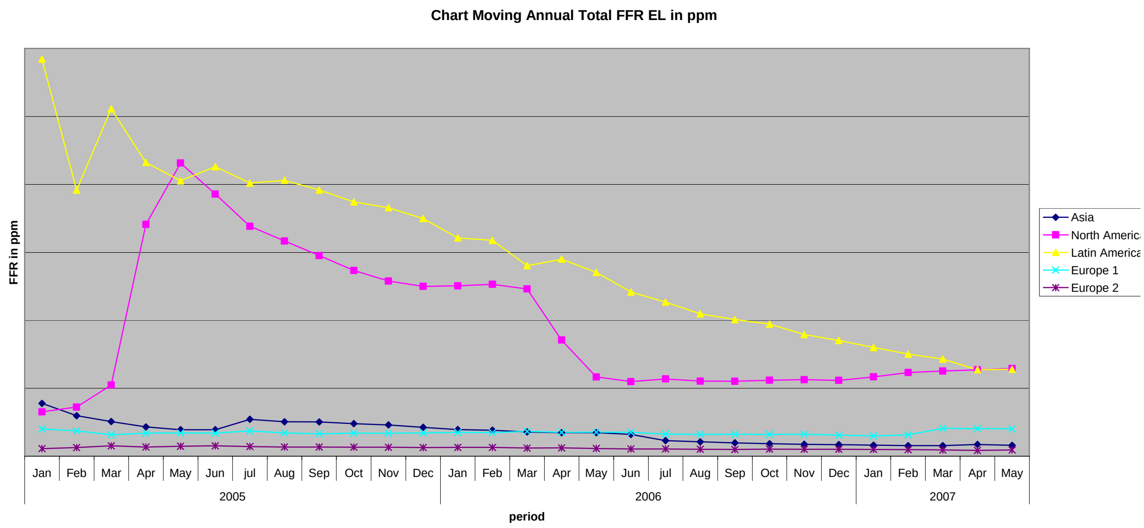


Figure 7-11: Regional FFR

2) Change in warranty terms

The four regional sister organisations of the case study company run relatively the same warranty policy. There is one major difference however, the case study company unofficially also reimburses labour costs. Does this reimbursement policy affect the claims and complaints? According to the described trend it should. The chart below shows the moving annual total of the warranty costs per organisation.

The case study company with its different warranty policy clearly shows a higher average costs level. The data is indexed for the number of supplies.

Also here the y-axis is removed for confidentiality purposes.

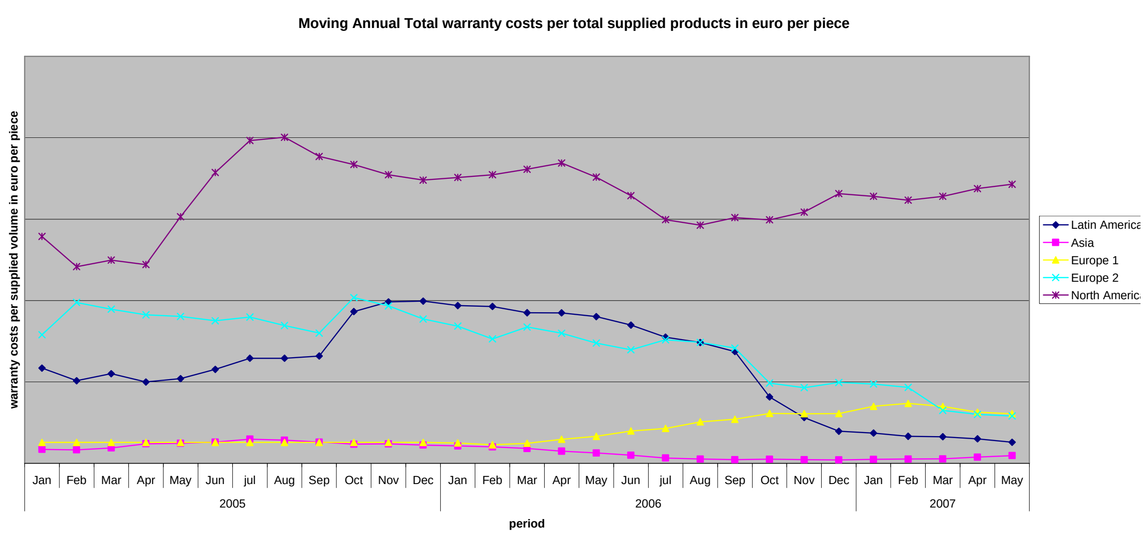


Figure 7-12: Influence of difference in warranty terms on claimed warranty

It proves that at the case study the labor costs cover for over 75% of the warranty costs. At the case study, like at all other regions, in some cases lamps are included under warranty. The warranty costs connected to lamps however are less than 0.1% of the total costs.

3) Increasing product functionality and complexity.

a) product complexity

First the products are segmented into two groups: new products (the electrical ones) and old products (the electro magnetic ones). The new products offer a large increase in functionality, as is described by the trend.

Next the number of product returns is compared to the sales volumes, resulting in field return rates. As can be concluded from the picture below the level of relatively returned new products is higher than that of the old products.

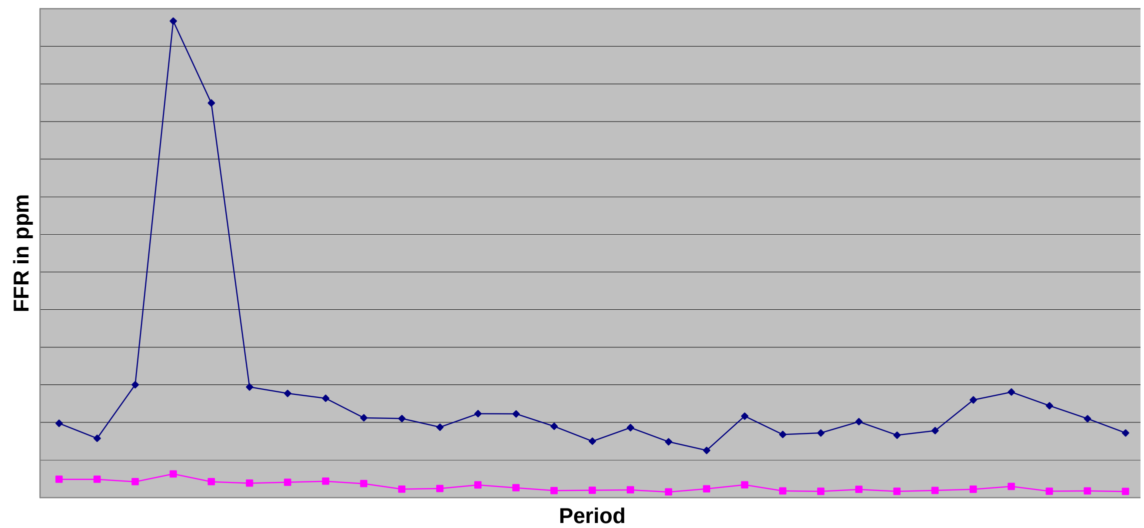


Figure 7-13: Monthly Field Failure rate new products (blue) versus old products (pink)

b) compatibility

To test literature findings on NO Fault Found/Fault not Found the researcher reviewed the ballast analysis results. Input from over 160,000 analysis resulted in the following top 80% of results:

- TESTED GOOD 25.25%
- OUT OF TOLERANCE 19.84%
- SHORTED 19.33%
- LEADS TOO SHORT TO TEST 9.15%
- BURNED 6.89%

Graphical representation of the data shows the % of No Fault Found and Tested Good is stabilizing at 25-30% after a dip in July and August. The dip can be fully explained by a short but exploding increase in the % of ballasts that could not be tested as a result of too short lead-in wires. If the lead-in wires are too short, the analysis cannot be done.

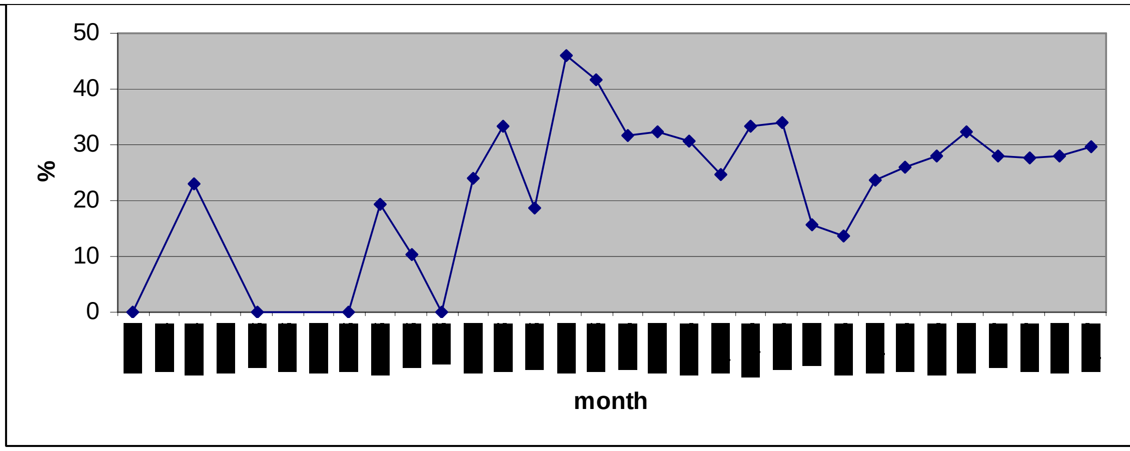


Figure 7-14: Percentage No Fault Found in analyzed products

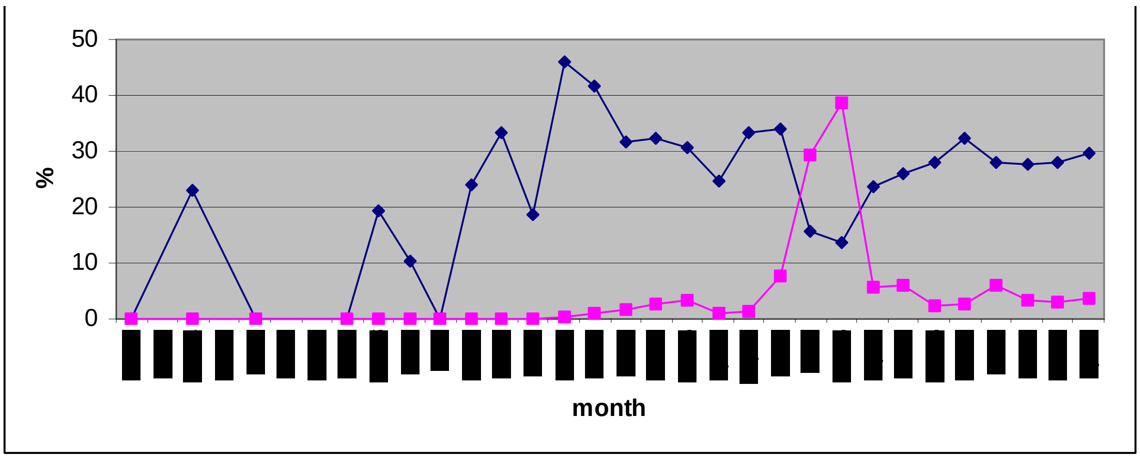


Figure 7-15: Percentage No Fault Found (blue) versus leads too short to test (pink)

Also BU2 performed an analysis of the test results for the electronic ballasts was done. This has lead to the following fault categories:
Fault categories electronic

- 30 % Concept
- 25 % Application
- 20 % No Fail
- 15 % Supplier
- 10 % Manufacturing

What is particularly interesting is that BU2 apparently is able to assign faults to the application.

In BU2 some research was done to find possible causes for the high number of No Fails. At 0-hr

- “easy way-out” for OEM: no cross check ballast (e.g. @ wiring mistake, bad contact)

In the Field

- Application problem (lamp, wiring); replacing ballast restores wiring
- Wrong ballast Class II application (not reported / no luminaire with complaint)
- Problem @ specific conditions, not mentioned/known and not reproduced
- Intermittent failure, not trapped by our test
- Group replacement; include good products
- Stop circuit activated (overtemp. / over voltage / End of Life lamp detection)
- Missing / insufficient problem description

Considering the fault not found percentages at other industries (up to 60% for mobile telephones) this 30% at the case study company can be considered quite low.

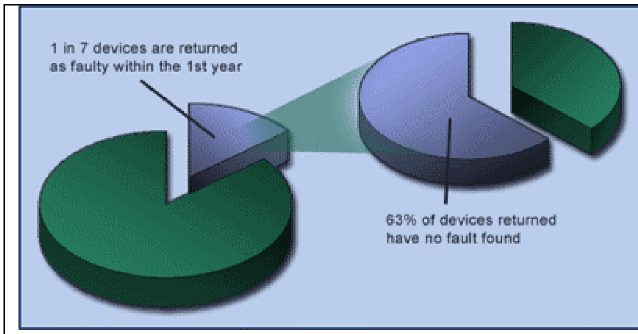


Figure 7-16: FNF in mobile phones industry [Ove 06]

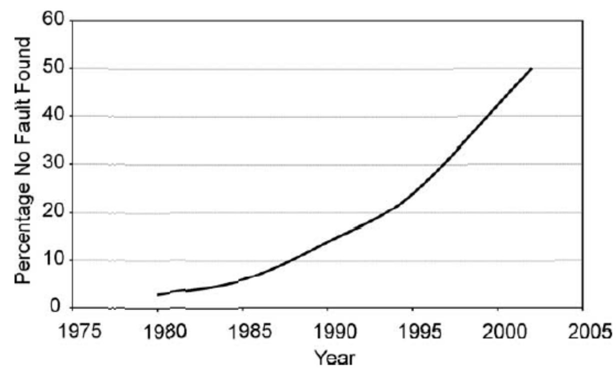


Figure 7-17: Percentage no fault found in modern high-volume consumer electronics [Bro 05]

In order to predict the costs for complaints and claims specifically those under warranty conditions one must understand the underlying fail distribution. As described in chapter 5.4.5 currently two models for failure distribution exist: the bathtub curve and the rollercoaster curve. Under a rollercoaster curve the costs are higher than under a bath tub curve.
All returned products of our case study are marked with a date code. This is the date the products were produced. Since the number of stock turns is above 12 for most products and since the organization is operating under a first in first out (FIFO) warehouse policy one can assume all products are sold and shipped to the customers within a month.
For all returned products also the date of the claim is recorded. Thus by extracting the date code from the claim code one retrieves the age of the product. In other words one can calculate the time the product was in the field before it was returned.
By using that information and plotting the number of returned products versus their age a failure distribution like plotted below can be retrieved. The picture below is created from all products that were returned in the year 2006. First a steep increase in failures. This could be explained by the time it takes the product to get into the application (some customers have the product in their warehouses for a longer period of time, some customers don't use FIFO but last in first out (LIFO) policies). The peak can be found just before the age of 1 year. After that gradually the number of returned products reduces. The maximum warranty period is 5 years. All products returned after those five years do not fall under warranty conditions.
The picture clearly shows that the bathtub curve model is not applicable. It rather resembles a roller coaster curve.
To test this curve also for one specific family group of ballasts the same picture was created. Here too a rollercoaster curve can be fitted. The first year peak is even more distinct.

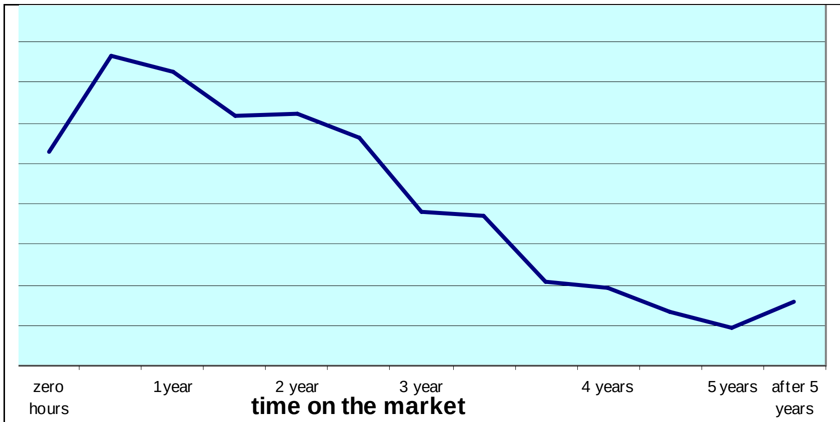


Figure 7-18: Number of products returned from the market versus the time on the market

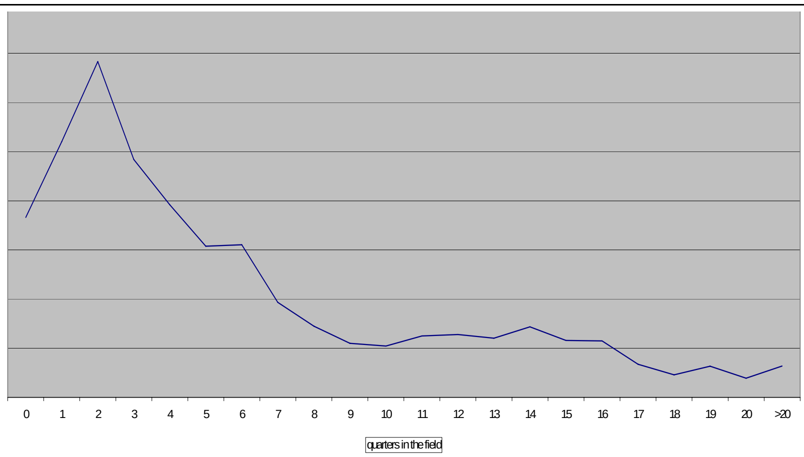


Figure 7-19: Number of specific family group products returned from the market versus the time on the market

7.7 Customer value surveys OEM & distributor

As expressed in the list of trends the customer demands are changing. Where customer demand is an input to product and service specification one can see customer perception as a result of experiences with these products and services.
On an annual basis the customer satisfaction is determined via telephonic codified interviews. A third party conducts these interviews. One year the Original Equipment Manufacturers are surveyed, the next year the distributors are surveyed.
The survey interviews take an hour and are processed into specific data analyzing software for data analysis.
The primary objective of the survey and data analysis is to assess the customer's satisfaction level with the company and its competition in the lighting electronics market.
For the purpose of the analysis the researcher decodified the survey results.

7.7.1 OEM satisfaction survey 2006

In the 2006 OEM survey 15 elements (attributes) were investigated.
The for this field survey important attributes are:

- Product Quality; Product field failure rates and line reject rates
- Technical or Application Support; Ability to provide technical, application and warranty support
- Field or Warranty Problem Resolution; Ability to resolve ballast field problems

Respondents were asked to rate the importance of each attribute, as it impacts the purchase decision, on the following scale:
1 = not at all important
5 = average importance
10 = critically important
Respondents were then asked to rate the relative supplier performance for each attribute on the following scale:
1= poor performance
5= average performance
10= superior performance

Based on the average attribute importance and the importance of that attribute in the 2004 survey all attributes are classified in one of 4 classes.
1) Low stated importance, high derived importance: Value-Added
•Customers value these but do not immediately recognize why - often described as “unarticulated needs”
•Opportunity for differentiation/leverage
•“Delighters” - these attributes are not expected, but good performance will increase satisfaction
2) Low stated importance, low derived importance: Low Yield/Emerging
•Secondary attributes that currently have little impact on the supplier evaluation decision
•May include emerging issues
3) High stated importance, low derived importance: Qualifiers
•“Must haves” - good performance is required for market participation
•“Dissatisfiers” - good performance in these attributes is expected, but poor performance will cause dissatisfaction
4) High stated importance, high derived importance: Key Drivers
•Areas of primary focus
•Exhibit strongest impact on supplier satisfaction
•“Satisfiers” - satisfaction is proportional to performance in these attributes
The attributes product quality and technical or application support both are classified as key drivers where “field or warranty problem resolution is classified as a qualifier.
The customer satisfaction survey report shows the average result of the company and its competition on all attributes. The company scores an 8.3 (product quality) a 7.7 (technical support) and a 7.6 (field resolution) on average. The competitors on average perform less.

7.7.2 Distributor satisfaction survey 2005

In the distributor satisfaction survey the for this field survey important attribute is:

- speed and quality of administering warranty returns, replacements and reimbursement

The same analysis methods are used.
Here warranty is found to be a key driver with an average score of 8.3. This is on par with the average competition.

7.7.3 A further analysis into information retrieved from the survey data

The satisfaction survey reports classify attributes but do not give insight into the deeper details of the customers satisfaction on the for our field survey important attributes.
At the level below the classification and the average score lies an area of information which is of paramount importance for the company.
A deeper analysis of the satisfaction survey data reveals satisfaction and importance scores per customer. Also satisfaction data per customer over the competitions performance can be found. The average score might show a high level of customer satisfaction but more important is to learn where the attributes act as a qualifier (dissatisfier) rather than as a key driver (satisfier) in the customer contacts.

Analysis of the survey results gave input to the two tables below.

Importance	1	2	3	5	6	7	8	9	10	Grand Total
1			1							1
2	1									1
4				1						1
5		1		1	1					3
6					1	1	1			3
7						2	1			3
8	1			1		1	3	2		8
9				1		3	3	6	1	14
10	2		1	3	3	8	7	10	17	51
Grand Total	4	1	2	7	5	15	15	18	18	85

Figure 7-20: results OEM satisfaction survey on specific warranty question

importance	2	3	4	5	6	7	8	9	10	Grand Total
2							1			1
4							2		1	3
5				7	1	3	5		3	19
6		1		1	1	8	5		5	21
7		1	2	1	2	16	6	7	2	37
8				1	2	6	28	20	10	67
9			1		1	5	18	13	7	45
10	1	1		5	6	8	16	20	34	91
Grand Total	1	3	3	15	13	46	81	60	62	284

Figure 7-21: results distributors satisfaction survey on specific warranty question

The cells in the two tables show the number of respondents. The top row shows the companies' performance score. The first column shows the importance level the respondent connects to the attribute. The red shaded area represents those customers that score an underperformance (5 and lower) where they assign a high importance (6 and higher). The green area represents those customers that score the company equal to or higher then there assigned high importance (so 10 OEM customers rated the company a 9 for their performance while they rate the question a 10 in importance).
Next to that it proved that 30% of all OEM respondents and 78% of all distributor respondents scored a competitor a higher score than they did our case study.

As a follow up to these findings the first objective for the company should be to learn why the "red" customers are unsatisfied with the companies' performance. Input from the "green" customers can be helpful to that end.
It is also interesting to learn why some customers rate a competitor of the case study a higher score than they do the case study company.

7.8 Create a detailed cause and effect diagram by interviewing stakeholders

Interviews were done with the chief executive officer, chief technology officer, chief operations officer, business line managers, sales managers, quality managers, quality engineers, customer service engineers, sales representatives and manager warranty process. All were asked what in their opinion are the main reasons for the increase in warranty costs payments and what in their opinion should be the solutions. The ishikawa diagram below pictures the responses.
Their inputs were used to validate findings and prepare for final feedback.

Stakeholder analysis can be used to generate knowledge about the relevant actors so as to understand their behavior, intentions, interrelations, agendas, interests, and the influence or resources they have brought – or could bring – to bear on decision-making processes. This information can then be used to develop strategies for managing these stakeholders, to facilitate the implementation of specific decisions or organizational objectives, or to understand the policy context and assess the feasibility of future policy directions [Bru 00].

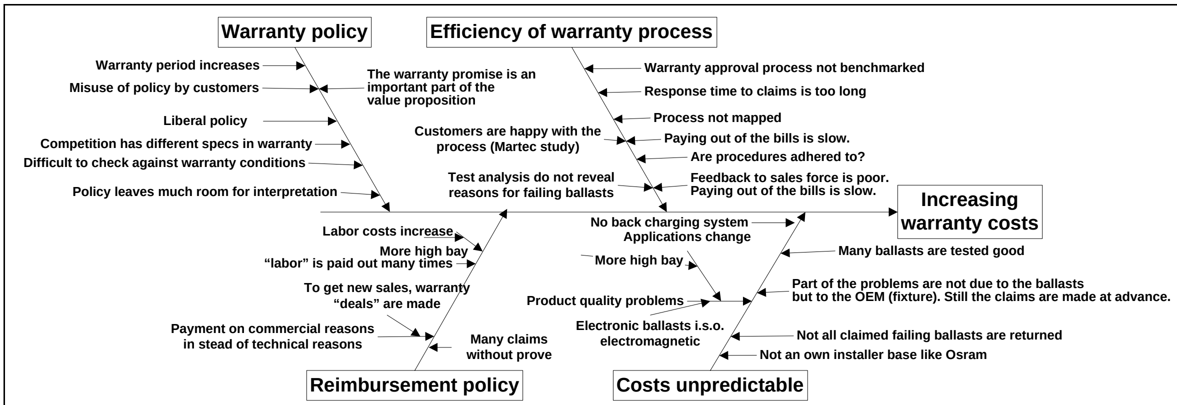


Figure 7-22: Cause and effect diagram with stakeholder views

7.9 Collect and compare warranty policies of lighting electronics manufacturers, suppliers and customers

7.9.1 A model for warranty terms

In order to quickly see what warranty policies cover regarding the three dimensions I developed the model below.

A short survey into existing warranty terms and conditions learned that one can distinguish three dimensions in a warranty policy in the lighting electronics industry. These three are:

- time: warranty coverage up to 10 years and more
- value ladder: extending from only ballasts up to full systems
- coverage: extending from material costs up to penalty clauses

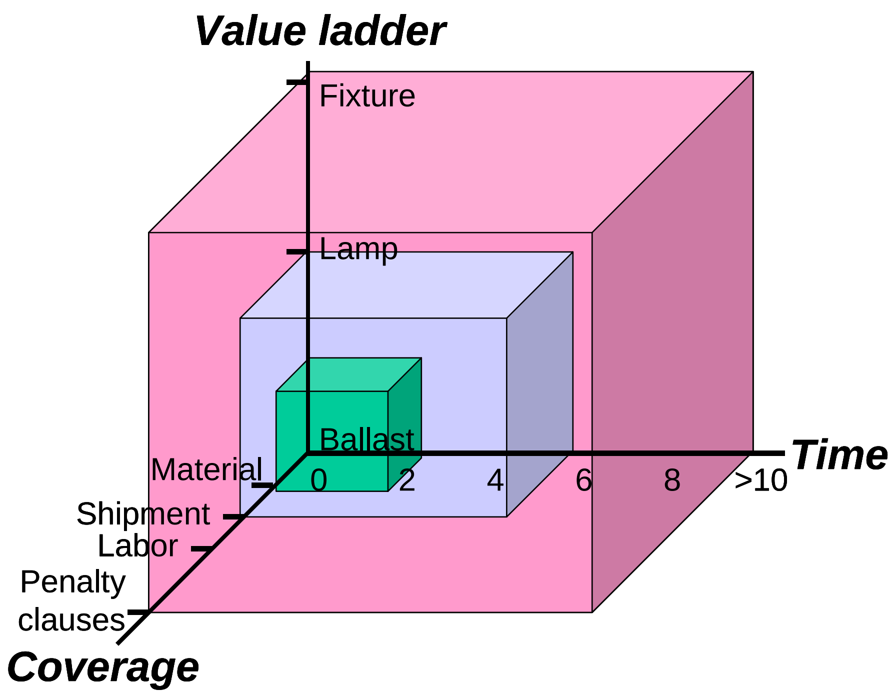


Figure 7-23: ballast warranty model

The return authorization data over 1 full year has been analyzed to find the contribution of specific elements from the warranty policy to the total warranty costs. The largest part of the costs can be found under labor. Roughly a third of the costs are found under material costs. Shipment costs cover 1% of the total. The replacement of lamps also covered for 1% of the total warranty costs.

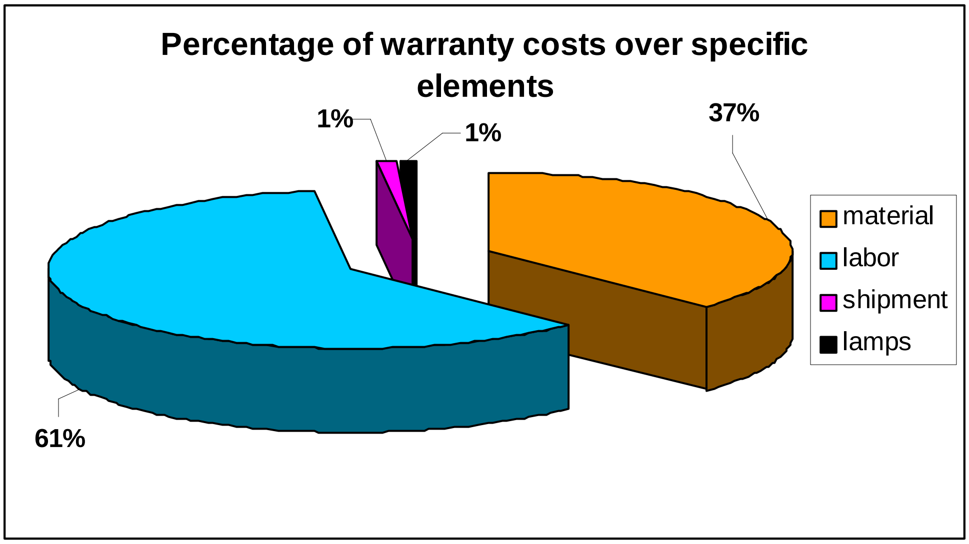


Figure 7-24: warranty costs division

The warranty policies of several "players" in the value chain were investigated in order to test the model and map their current warranty policies.

7.9.2 The warranty model applied to the value chain

<u>Manufacturers</u>
There are four big players in the Lighting electronics industry: Philips, Osram/Sylvania, General Electric (GE), United Lighting Technologies (ULT).

GE and OSRAM/Sylvania for some systems offers warranty for both lamps (own brand only) and ballasts. The ballasts carry a 5 year warranty under which labor is covered as well.
Philips offers some lamp ballasts system warranties from 5 up to 8 (in Europe) year. The lamps under warranty are also non Philips brands (for the US). Their policy does not cover labor.
ULT in its warranty policy covers ballasts up to 5 year. They do not cover labor nor lamps.
Several other ballast manufacturers offer warranty periods up to and over 10 years. In one case a warranty of 50 years was offered. These manufacturers typically are small organizations without an own sales channel. Further research showed this warranty can be read as "lip service" since no costs and no materials were covered.

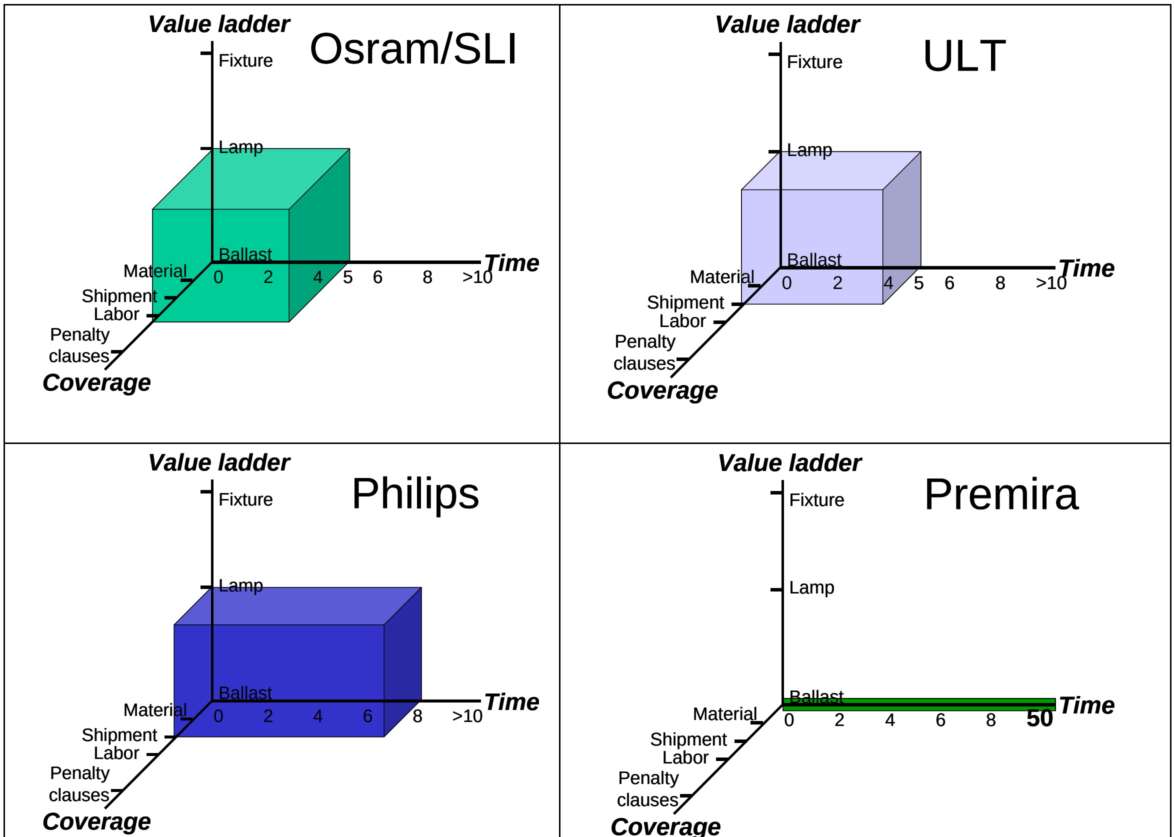


figure 7-25: Manufacturers warranty

OEMs / Distributors
Other Equipment Manufacturers are typically fixture manufacturers. The big 6: Cooper, Genlyte, Acquity, Hubbell, LSI, Philips. Some big distributors are Sonepar, REXEL, WesCo, Hagemeyer, Home Depot.

Most OEMs exclude ballasts from their warranty. They refer to the original manufacturer. Only a few include the ballasts. Their warranty period is at maximum 2 years for the system. This is not different from the wholesalers and distributors where in many cases no warranty information is supplied.

Suppliers to the lighting electronics industry
Typically the warranty conditions for the lighting electronics components are discussed between supplier and manufacturer. Their warranty terms and conditions are found back in sales contracts rather than on official external documents. The components are purchased based on cost price and specification.

Conclusion:
In the total value chain the component suppliers are not selected for their warranty terms and conditions. As such these don't offer official external documentation for warranty. Lighting electronics companies do publish warranty policies.
There is differentiation in warranty policy terms and conditions regarding time, value ladder and coverage.

OEMs, distributors and wholesalers, if they have a warranty policy, in most cases exclude the ballasts from their warranty terms. Where they don't exclude ballasts, their system warranty is to a maximum of 2 years.

7.9.3 The warranty model applied to the case study

The warranty model can also be used to plot predicted and current costs. In figure 7-25 the curve represents the costs paid for replacing products of a certain age. Figure 7-26 shows the costs for labor. The green block is the 3 years warranty period that most companies offer. The pink block is the extended 2 years several companies offer.

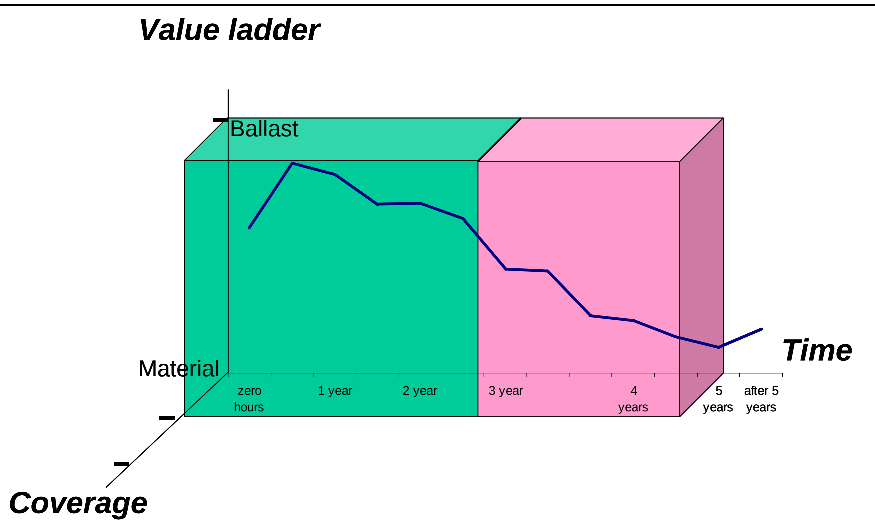


Figure 7-26: The warranty model with costs per product age

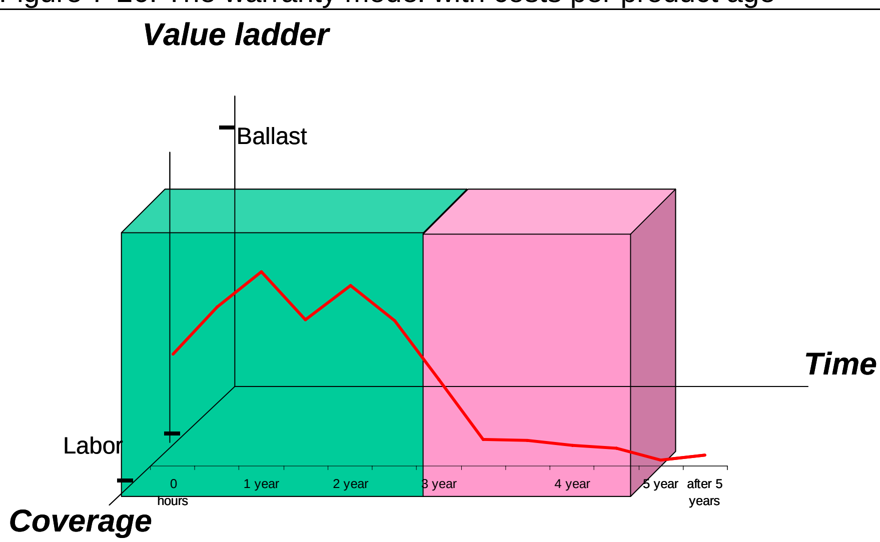


Figure 7-27: The warranty model with costs for labor per product age

Chapter 8 Synthesis

8.1 Conclusions and recommendations:

1.Trends
It can be concluded that the found trends behind the increase in customer complaints at the consumer electronics retail industry are also relevant for the lighting electronics business-to-business environment (paragraph 7.1)

A company cannot change the trends itself. Companies rather should take benefit from understanding the backgrounds of these trends and be pro-active in using this new acquired knowledge in their customer contacts. Those contacts are not solely organized via field feedback or complaint management, but typically follow all the contacts in the pre purchase, the purchase and the post purchase phase as indicated by the customer touch point wheel or the consumer experience model (paragraph 5.5.1)

Some of the described trends are typically better related to the scope of this thesis. Trends 6 and 7, changing warranty conditions & timely field feedback availability have the highest correlation to the thesis' scope. Therefore most of the research was done on those two trends. Conclusions to these two trends are under 2) and 3).

2. Field feedback
At the case study company several field feedback loops (paragraph 5.6) do exist. Complaint handling (paragraph 5.2.2) is well organized and documentation is done via the companies enterprise information system. The feedback loop focus is primarily on costs control and product replacement. These loops however do not fully cover the information as required for doing a full root cause analysis on lighting system/application level (paragraph 7.2).
This is also found by using a different analysis technique, Maturity Index Reliability (paragraph 5.6.1 & 7.4). It becomes clear the case study organization does have a single but small field feedback loop in place at Maturity Index Reliability level 3 but the majority of the loops do not reach above level 2. And when it comes to the payment process, the main focus the Maturity Index Reliability level is 0.
The information loops are interconnected but apart from the bulletin board information exchange does not take place.

Above all one should realize that there are more ways in retrieving customer feedback than via complaint handling alone (paragraph 5.3 & 5.5).
In order to change the focus from costs only to also including customer satisfaction (paragraph 7.2.4) organizations should create a field feedback system aimed at retrieving that information that provides an insight in what is happening at the customers' site. Several companies provide a service in replacement, re-lamping, re-equipping lighting systems. Some lighting electronics companies own such service providers; others hire these to do their warranty replacements.
The insights these service providers have in actual field problems and the possible root causes for these are of enormous value. Though still there is no information available that these service providers are actually made part of the field feedback loops.

Furthermore the feedback from the field should be processed to all relevant organizational entities / business processes without any time gap (paragraph 5.5 & 5.6).

3. Warranty coverage

In the total value chain the component suppliers don't offer official external documentation for warranty. Lighting electronics companies do publish warranty policies.

There is differentiation in warranty policy terms and conditions on three axes: time, value ladder and coverage (paragraph 7.9).

Original equipment manufacturers, distributors and wholesalers, if they have a warranty policy, in most cases exclude the ballasts from their warranty terms. Where they don't exclude ballasts, their warranty is to a maximum of 2 years, so never extending the ballast ones.

Currently lighting electronics companies are mainly focusing on the time axis and the coverage axis. The warranty on the value ladder for the bigger companies includes in many cases lamp-ballast combinations. Research learns that the costs for including lamps in the warranty are not dramatic (paragraph 7.6.1). The same goes for the time axis. The typically found roller coaster curve (paragraph 5.4.5 and 7.6.1) for product failures sees the vast majority of failing products doing so before passing warranty time level.

The biggest impact on actual costs payment can be found in the coverage axis. From the case study is learned that labor covers for about 75% of total warranty costs (paragraph 7.6.1).

However although expanding the time line does not show a big increase in products returned, it does offer opportunities for customers to longer claim versus the coverage axis. And considering the costs related to those axes an increase in time could mean an indirect increase in warranty costs via the coverage axis.

A model has been developed (paragraph 7.9.1) that can be used to picture the warranty proposition and at the same time act as a means of showing total costs under warranty (paragraph 7.9.2 & 7.9.3).

Organizations should first picture their current warranty policy and next include their product failure probability distribution, connected to the failure distributions of other elements from the value ladder. The extension of coverage from the product into next levels should be done only when field feedback information predicts that the increased sales outgrow predicted warranty costs increase.

Therefore it is highly recommended not to run a "me too" policy on warranty. The organizations with the most accurate field information and the best field feedback loops, reaching the deepest into the organization will have a serious advantage on other organizations. For sure an increase on the time axis will have serious effects on warranty costs in case the coverage axis is increased outside products only.

Furthermore it is advised to further research what conditions suit best for what product-market combination.

4. Analysis

Analysis is done on components level rather than system/ application level (paragraph 7.2, 7.4, 7.6.1). This does feed the organization with information to better cover for component/supply related problems, which relates back to trend 2 "subcontracting and outsourcing".

The Return Material Authorization centers focus their analysis on the product and its components whereas the "product – lamp – fixture – system – application" environment interaction might hold the main root causes for the product "failure".

The percentage of No Fault Found at the Return Material Authorization centre (which is comparable to those found at other case studies (paragraph 7.6.1)) can act as an indicator for that. As is described in literature (paragraph 5.4.5) product reliability is no longer dominated by component failures.

Still at the case study to a large extend the analysis reveals product failures within the product, be it soldering, circuit or component caused failures.

Recommendation is to maintain the RMAs as a platform to be able to detect in-product failures that can be related back to all stakeholders (design/ supply/ manufacturing/ consumer).
As a next level organizations should ensure to retrieve actual application information. Either via own or independent service organizations or by requesting the “claimer” to provide actual application information (like fixture temperature, wiring pictures, humidity measurements, lamp and fixture details, power measurements).
Not only will this information provide input for a full root cause analysis it also creates a possibility to refine product specification in order to create more robust products capable of withstanding more violent operating conditions and acting as a net for less reliable lighting system components (lamp, fixture, controls, power supply).

5. Processes
The process map shows 9 main processes under warranty/ complaint handling (paragraph 7.3). The complaint handling process itself is well organized and meets most criteria as found in literature (paragraph 5.2). The results of the field study show (paragraph 7.2) that the main focus is on costs and product replacement. That focus becomes very clear in all the decision ‘diamonds’ in the process map (annex III). The field study also tells that objective criteria are used to decide whether or not a claim is paid. However (paragraph 7.2) the customer dispute process makes it possible to pay out customers even if the claim does not meet internal criteria. The field study did not focus on the phenomenon of customer dispute payments (commercial considerations). The study showed that the customer dispute process is the only process in the total process map that is not well connected to the enterprise information system.

In order to simplify the warranty/complaint handling process on one hand and shifting focus from only costs to costs and customer satisfaction organizations need to learn more and faster what issues arise in the field. Fast field feedback, preferably recovered by own or hired organizations, holds the key to that end.
If field information is collected in the field instead of being reconstructed partially via Return Material Authorization and hotline (paragraph 7.3) than it could speed up decision making, and better instruct return material authorization what to search for in those cases where the application itself does not show the root cause.

6. Data collection
At the case study all complaint and claim information is loaded into the enterprise information system (paragraph 7.5) So there is an enormous amount of valuable information available. It does take the organization however a fair amount of time and resources to capture that information and to learn from it.
The dataset is not free from errors (paragraph 7.5) so filtering is needed before analysis can be done. Furthermore it takes quite some time to identify products (date code, can code, warranty coverage).

It is advised to do further research in how to ensure data errors are not accepted by the system. It is also advised to search for and include warranty costs reporting modules in the enterprise information system.
Furthermore organizations should ensure identification of products gets done fast and with a number of attributes (e.g. via bar-coding).

7. Customer satisfaction.
The case study company performs customer satisfaction surveys to learn what the customers find important and what their perception of the companies performance is (paragraph 7.7). Average results show good performance. Behind the average are satisfied customers but also customers who are not satisfied. Some customers are more satisfied with competitors.

It is recommended to use the account managers to use the satisfaction survey information to better learn what dissatisfies their customers.
First objective for the company should be to learn why the "red" customers are unsatisfied with the companies' performance. Input from the "green" customers can be helpful to that end.
It is also interesting to learn why some customers rate a competitor of the case study a higher score than they do the case study company.
It is advised to include also other staff, like technicians, in customer visits (paragraph 5.3).

8.2 The hypothesis

In a lighting electronics business-to-business environment as well as consumer electronics retail environment an increase in customer complaints is found.
This is caused by several trends leading to a growing number of products that are not satisfying the customer needs and expectations.
The absence of a well functioning field feedback system to learn from customer experience and behavior further amplifies this increase.

The results of the case study that was aimed to test the hypothesis:

- Positive test on increase in customer complaints at lighting electronics business-to-business
- Positive test on the applicability of the found trends. No test done on correlation of each separate trend with increase in complaints. However the case study did bring forward clues that such a correlation does exist.
- Positive test on absence of well functioning field feedback system. Positive test on not learning from customer behavior. Case study company does learn from customer experience but not to its full content. So that part of the hypothesis could not be fully confirmed.

Therefore the hypothesis can be translated into the following statement:

In a lighting electronics business-to-business environment as well as consumer electronics retail environment an increase in customer complaints is found.
There are several trends and combinations of trends that very likely cause this increase.
The absence of a well functioning and mature field feedback system to learn from customers' experience and behavior contributes to the increase.

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