MASTER

The control of the flow of the repairable spare parts

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Award date:
1993

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Master Thesis report

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Abstract

A concept for the control structure for controlling the flow of the repairable spare parts, is presented in this report. The determination of the basic structure, the planning and control concept, the logistic organization and the performance measuring system are described. For one product market combination, the more theoretical description of the control structure is brought into practice.

Preface

This report presents the results of my Master Thesis project, which has been carried out within the International Support Group of Philips Industrial Electronics (IE). This project is part of the study 'Industrial Engineering and Management Science' at the Eindhoven University of Technology. The assignment of the project dealt with the improvement of the control of the flow of the repairable spare parts.

This report is primarily intended for the officers of the service departments of the Operating Companies of Philips IE. I think, especially the chapters 5-9, should be of interest to those officers.

It would not have been possible to carry out the project without the cooperation of many different people.
From the Eindhoven University side, the project has been supervised by Ir. P. Gosselink and Ir. C.P.M. Govers whom I thank for their valuable contributions and criticism.
Herewith, I would like to thank the Philips employees who always did their utmost in providing me with information or in helping me to execute the project. In particular I want to thank:

- Jan Sauvé, Fluke Europe B.V., for making this assignment possible and for coaching me the first six months of the project;
- Annette Steinbusch, Philips IE International Support Group, for coaching and supporting me during the whole project;
- Cor Lieberwirth and Tammo Tibben, Philips Consumer Service, and Hans van Doorn, Philips IE Operating Company Electron Optics, for providing me with valuable information;
- Patrick van Lierop and Pieter Verbeek for making some figures and helping me with the realization of the lay-out of this report.

In addition, I want to thank: all the members of the International Support Group for giving me a nice time during the project, my room mates for their continuous support in the periods of ups and downs of the study and furthermore everyone, not mentioned by name, who has contributed to the realization of this report.

Johan Graveland
Eindhoven, November 1993

Summary

At Philips Industrial Electronics (IE) a Total Quality Management (TQM) project is running. The aim of the TQM project is a continuously process improvement leading to improved customer satisfaction, employee satisfaction and increased profitability.

Within the TQM project, it is amongst others necessary to monitor and control the return flows of the spare parts. The return flows of spare parts can roughly be divided in a flow of spare parts for repair and in a flow of spare parts for return to central stock.
The other reasons to investigate the return flows of spare parts are:
- to achieve 'zero stock' in the European National Sales & Service Organization (NSO's), the IE spare parts supply policy, it is necessary to design a concept for the control of the return flows.
- the expected environmental legislation leading to the 'take back' obligation for the vendor.

Within the TQM project and the spare parts supply policy, the following assignment is defined: *Considering the characteristics and the financial aspects of the return flow of repairable spare parts, design a concept for the control structure of the return flows and develop performance indicators to measure the performance of the return flow process.*

The results of the problem diagnosis phase is that the existing control method of the return flow of repairable spare parts causes the following problems:
- Long and unreliable leadtimes; tardiness exists in about 50% of the goods movements of the return flows from the NSO's to Philips Consumer Service (PCS), and tardiness exists in about 45% of the goods flow of repaired parts from the Repair Centres to PCS. (PCS is the central warehouse of IE spare parts)
- High inventory levels in the entire chain; especially caused by the lack of integral inventory control in the entire chain and the long and unreliable leadtimes.
- The delivery performance of PCS concerning IE spare parts is 80%, while the target is 95%.

The main causes are the lack of agreements concerning the return times from the NSO's to PCS, the lack of agreements with the Repair Centres, the incorrect inventory control, the lack of logistic organization and the absence of performance measuring system.

In order to realize a higher customer satisfaction while decreasing the integral logistic costs, the existent way of control has to be improved.
To improve the existent situation it is necessary to use an integral approach. The whole repair logistic chain has to be considered, to avoid sub-optimization. A concept for the integral control structure is described. The most important step is the definition of the basic structure. The existent basic structure has to be simplified. With a simplified basic structure the leadtimes and the leadtime variation can decrease.

The defined basic structure has to be controlled. Within the control concept, agreements should be made between the service department of the Operating Company (OC) and the NSO's, concerning the return times. Also agreements have to be made between the service department of the OC, PCS and the Repair Centres concerning repair and test capacity reservation, repair leadtimes and average repair batch sizes.

A prerequisite for a fast and reliable flow of repairables is a well defined logistic organization. The service department of the OC is responsible for the entire repair flow; within the service department one person has to be the 'process owner'. When tasks are delegated to other entities, the person remains responsible.

The performance has to be measured to ascertain the extent to which kind and nature the current repair services meet actual market requirements. The performance has also to be measured to control the performance of the entities involved in the return flow of repairables (important topic in the TQM project). When set targets are not realized, decisions must be taken to improve the current situation. An improvement of the current situation can result in a change of the organization, the control structure or even the basic structure.

The determination of the information needs and the determination of the information systems are not elaborated in this report. Both aspects are very important to realize performance improvement, because the right information is needed to support the logistic decisions. So further investigation is necessary on both aspects.

To set a process of improvement in motion, the service department of the OC has to initiate this process. The above mentioned actions have to be executed and the aspects information needs and information systems have to be further investigated.

The concept of the control structure is practised for one product market combination of the OC Electron Optics (EO). Integral costs saving of approximately 45% are possible when the basic structure is simplified. In case of leadtime reduction costs savings of about 60% are possible.

List of abbreviations

CICS	Customer Inquiry Control System
CSS	Communication & Security Systems
DOSI	Direct Ordering, Shipping & Invoicing
EO	Electron Optics
IE	Industrial Electronics
IFG	Issue Frequency Group
ISG	International Support Group
MSH	Main Stock Holder
NO	National Organization
NSO	National Sales Organization
OC	Operating Company
PCS	Philips Consumer Service
PD	Product Division
SSP	Standard Stock Price
TQM	Total Quality Management

Chapter 1 Introduction

The Philips Product Division Industrial Electronics (IE) provides standard and custom made products, systems, projects and services for professionals in several markets. The markets are industry, scientific establishments, service organizations and governmental bodies.

To support the operation of the IE products, systems and projects at the customers' sites, IE maintains an inventory of spare parts. The total supply chain of spare parts includes: the Philips Supply Centres and the external suppliers (the suppliers of the spare parts), Philips Consumer Service (PCS) as the central stock point, the national warehouses from the National Sales & Service Organizations (NSO), the field service engineers and the customers.
During the last three years, stock reduction is realized at PCS and at the NSO's. To continue this stock reduction, a spare parts supply policy has been defined one year ago. The aim of the IE spare parts supply policy is to achieve zero stock for non-kitted spare parts in the European NSO's. This means no physical stock other than kits, boxes containing parts for diagnostic and/or repair, at the national warehouses. The four key issues to achieve zero stock for non-kitted spare parts in the European NSO's are:

- Direct Delivery: the delivery of spare parts from PCS directly to the engineers or even to the customers. It is only possible to remove existing NSO stock when there is another fast and reliable supply of spare parts to the engineers and the customers.
  Direct Delivery exists for Germany, United Kingdom and France (partial).
- Kit management: to control kits, knowledge about the contents, the location and usage of the kit is needed.
- Local for local parts: in some NSO's not only spare parts are used from Philips Supply Centres and PCS but also from local suppliers. Negotiations have to be made with local suppliers that they will keep these parts on stock.
- Return flows: defective repairables, serviceables (these parts are new, not used; the engineer ordered them to repair an apparatus but it turned out that they were not necessary to repair the apparatus), dead on arrivals (some new parts turn out to be faulty on receipt and cannot be used to repair the apparatus) and wrong deliveries have to be sent back to PCS to achieve zero stock at the NSO's.

In this report a part of the return flow of spare parts is further investigated. Within the return flow two sub-flows can be distinguished:

1. A return flow of defective spare parts for repair. Many parts are thrown away if they are diagnosed as defective. The most valuable parts, however, are sent back for repair.
2. A return flow of serviceables, dead on arrivals and wrong deliveries. The NSO's want to return spare parts if they have no function at the national warehouses.

Only the logistic aspects concerning the flow of the repairable spare parts, sub-flow 1, are described in this report. The logistic activities, concerning the flow of the repairable spare parts, are not good coordinated at the moment. Coordination of the logistic activities is a condition to realize customer satisfaction improvement, while decreasing the integral costs. In this report an integral control system for repairable spare parts is described, to coordinate the logistic activities.

The decision rules for classifying items as repairable will not be considered in this investigation. The repair or throw away trade off is described in the report: 'Control of repairable spare parts at Philips Medical Systems' written by De Man [7].

In conclusion of this short introduction, the survey of this report is given.
In chapter 2 the characteristics of Philips, and especially of the Product Division Industrial Electronics, are described. This chapter serves as an introduction to the Philips organization for those who are unfamiliar with it.
The assignment and its background are formulated in chapter 3.
The working method and investigation methodology are mentioned in chapter 4.
A pilot study is executed for a better understanding of the qualitative and quantitative aspects of the return flows. The pilot study results in the description of the logistic characteristics of the repair process and in a problem analysis, discussed in chapter 5.
According to the results of the problem analysis a concept for the integral control structure of the repairable spare parts is described to improve the existing performance.
The first step is the determination of the logistic basic structure (chapter 6), followed by the determination of the control concept, the logistic organization and the performance measuring (chapter 7).
The more theoretical description of the control structure is brought into practice for one product market combination of the Operating Company Electron Optics, see chapter 8.
The conclusions and recommendations are shown in chapter 9.

Chapter 2 Characteristics of Philips

2.1 Philips Electronics NV

The Philips Group is a multinational company operating in the electronics and lighting branches. Philips operates worldwide in about sixty countries. The total number of employees amounts to 252.200 (01-01-93). The total turnover of the company is Dfl. 58,5 milliard in 1992. About fifty percent of the turnover is realized on professional markets and fifty percent on consumer markets.

Recent years have shown radical changes on professional and consumer markets. The decreasing consumer market is one of the reasons that 1990 was one of the most eventful periods in the company's history. To ensure the continuity of Philips, throughout the company a process of change has been set in motion which is named Operation Centurion. The only goal of Operation Centurion is to increase the profitability. To attain this goal, it is necessary to concentrate on core businesses and to improve the customer orientation and process quality throughout the entire chain of activities.

Ranking to turnovers, Philips takes the seventh place in the top ten of the world's leading companies in the electronics sector.

The organization of Philips Electronics NV is structured along two axis: the organization of activities by Product Division and the organization by country, the so-called National Organization. The product-related activities are divided into Product Divisions. Within a Product Division the activities are based on similar markets and the use of similar technologies. The Product Divisions are responsible for world product and market policy. The country-related activities are divided in more than sixty National Organizations. The National Organizations are responsible for general policy regarding sales & services in their country, while maintaining close links with the Product Divisions. The overall management of Philips Electronics NV is executed by the Group Management Committee. The structure of the Philips organization is depicted in figure 2.1.

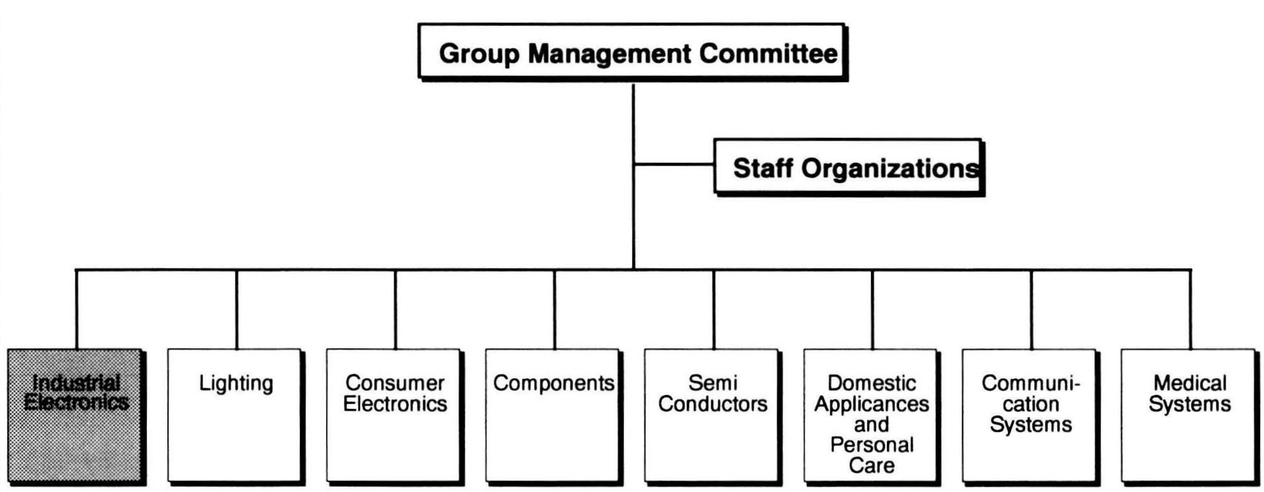


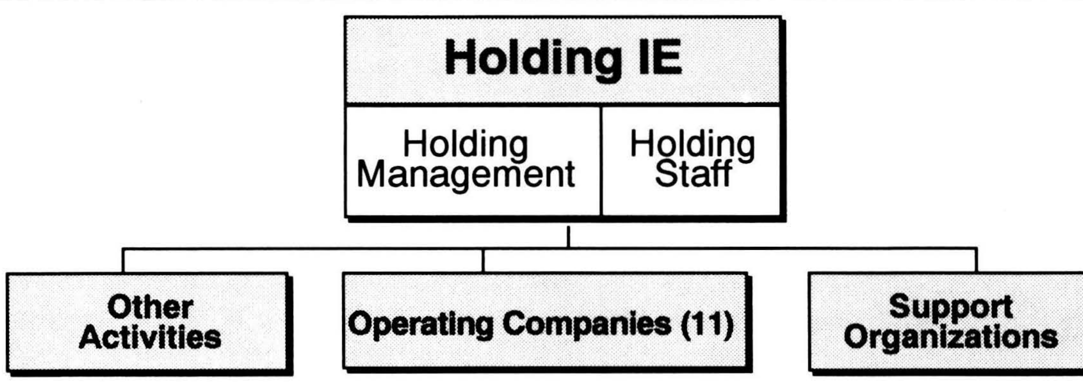
Figure 2.1: Organization Structure Philips Electronics N.V.

2.2 Philips Industrial Electronics

The Product Division Industrial Electronics (IE) operates on a worldwide basis in fields as diverse as industry and commerce, training and education, research and development, public utilities and governmental authorities. The IE division provides standard and custom-made products, systems, services and projects in the areas of amongst others: systems for monitoring and measurement, materials analysis and process control, personal and public communication and electronic security.

The annual turnover of 1992 amounts to Dfl. 1.9 milliard. About 6700 employees are working within IE at the moment.

The organization structure was changed on January 1st, 1993. The old structure was Business Unit-oriented. These Business Units had their own areas of expertise. As a result of Operation Centurion a process of change has been set in motion which resulted in an organization structure change for IE. The organization structure change causes the necessary disentanglement of the IE activities, which is still going on. Now the IE organization structure has the shape of a Holding with eleven highly autonomous Operating Companies (OC), five other activities and Support Organizations. The new organization structure is depicted in figure 2.2.



Other Activities

EDAX	Mahwah
Gen. & Counters	Kista
Prof. Building Blocks	Almelo
Ph. Autom. Projects	Kassel
Ph. Spec. Eng. Proj.	Eindh.

Operating Companies (11)

Ph. Analytical X-Ray	Almelo
Ph. Comm. & Security Syst.	Breda, Oslo Eindh. (TQ)
Ph. Electron Optics	Acht
Ph. Electr. Mfg. Technol.	Eindh. (BAF)
Ph. Industrial Autom. Syst.	Eindh. (TQ)
Ph. Industrial X-Ray	Hamburg 63
Ph. Power Systems	Wavre
Ph. Proc. and Mach. Autom.	Kassel
Ph. TV Test Equipment	Brondby
Ph. Weighing	Hamburg 73
Thermocoax	Suresnes

Support Organizations

- per country
- per Plant
- Internat. Support Group

Figure 2.2: The IE organization structure

The Holding management is responsible for: General management, Administration and Finance management and Human Resources management.
The key tasks of the Holding staff are: Strategy and Portfolio management, Legal Counsel, Financial Control, Management Development, Automation & Technology and Communication & Public Relations.

Each Operating Company is fully responsible for its entire business chain: development, manufacturing, marketing, sales and service. Each OC has its own market segment with its own specified activities.

The Support Organizations support the Holding and the OC's, see section 2.3.

This new market-oriented structure will create opportunities for successful Total Quality Management (TQM). IE has reorganized the organization structure in order to implement TQM successfully. The aim of the TQM-project within Philips, and especially at IE, is a continuously process improvement leading to improved customer satisfaction. The TQM-concept is being considered as a 'journey' which will take IE via the ISO 9001 certification and the Philips Quality Award (PQA-90) to the fundamental objective of becoming the customer's 'first choice' in 1995. All entities in the IE organization have made TQM-plans and will use performance indicators to see whether goals are being achieved.

2.3 IE Support Organizations

The total IE Support Organizations consist of National/Regional Support Organizations, Support Organizations in Eindhoven and Almelo, and an International Support Group, situated in Eindhoven.

The National/Regional Support Organizations are responsible for managing national or regional shared resources.

The Support Organizations in Eindhoven and Almelo are responsible for e.g. security, facility management, plant services, packaging design.

The International Support Group (ISG) has been formed to support the Holding, the OC's and third parties. The mission statement of the ISG is: to be first choice supplier of dedicated services to IE and other Philips related activities in improving their businesses and in supporting them with respect to their joint activities. The ISG supports on the basis of contractual relationships. The support activities can roughly be divided in: Business Training, Customer Support, Standardization and Environment, Marketing & Sales, Innovation, Quality Assurance, Purchasing, Physical Distribution, Business Engineering, Accommodation, Logistics & Manufacturing and Marketing Communication.

One of the activities of Customer Support is the improvement of the spare parts supply chain.

Chapter 3 Formulation of the assignment

Background of the assignment
Shortening product life cycles, asking for short and reliable delivery times and increasing product assortment puts increasing demands on the logistic process of companies. Flexibility, quality, continuous integral process improvement and customer orientation are the key words for now and the future. Philips IE responds to this development by means of, amongst others, the IE spare parts supply policy.

The overall objectives of the IE spare parts supply policy are:
- To provide the customers with a service adequate for the requirements of the 90's, leading to improved customer satisfaction.
- To achieve a high level of consistent speed and reliability of supply for the European market, through a lean logistic chain, distribution network, from Philips Consumer Service (PCS) to the customer. PCS is amongst others specialized in the distribution of spare parts.
- To lower the integral service costs.

The aim of the spare parts supply policy of IE is to realize:

Zero stock for non-kitted spare parts in the European NSO's.

This means no physical stock other than kits, boxes containing parts for diagnostic and or repair, at the national warehouses. The four key issues to achieve zero stock for non-kitted spare parts in the European NSO's are:
- Direct Delivery: the delivery of spare parts from PCS directly to the engineers or even to the customers.
- Kit management: to control kits, knowledge about what the kit contents, where the kit is located and which customers can use the kit, is needed.
- Local for local parts: the spare parts delivered by external local suppliers must also be on stock at the suppliers locations.
- Return flows: defective repairables, serviceables, dead on arrivals and wrong deliveries have to be sent back to PCS to achieve zero stock at the NSO's.

Assignment
Considering the characteristics and financial aspects of the return flow of repairable spare parts, design a concept for the control structure of the return flows and design performance indicators to measure the performance of the return flow process.

Chapter 4 Working method

4.1 General

The process of organizational investigation can be divided in four phases:
1. problem diagnosis;
2. development of the problem solution;
3. implementation of the solution;
4. evaluation of the implemented solution.

In this report only the first two investigation phases are considered.

The ultimate way in which the investigation will be executed depends on the chosen investigation methodology. The use of an investigation methodology is one of the conditions for a successful investigation result; the methodology is the guideline for the investigation process. In Dutch literature many methodologies exist: De Leeuw, Van der Zwaan, Van Kempen, etc. In all these methodologies the above mentioned process phases can be distinguished.

The method of Van der Zwaan [12] is chosen for the elaboration of the first phase. The method of Van der Zwaan describes, in a detailed way, how to elaborate the problem in a problem definition. Diagrams are used in the elaboration of the problem to visualize relations between the several aspects of improvements. The elaboration process of the problem can be divided in five sub-phases: justification, problem formulation, knowledge/understanding gathering, problem analysis and the demarcation (see section 4.2).

For the elaboration of the second phase, development of the problem solution, the integral logistic approach from Hoekstra & Romme [6] is used. The integral approach is a condition for a structural improvement of the flow of the repairable spare parts in the *entire* chain; it is necessary to avoid sub optimization. In the integral approach the goods flows, logistic organization and control systems will be investigated in coherence. The following aspects are determined:
1. objectives;
2. characteristics of product, process and market;
3. basic structure of the company;
4. planning and control concept;
5. logistic organization;
6. information needs;
7. information systems and procedures.

The elaboration of the aspects one until five are handled in chapter 6 and 7. Given the available time it was impossible to elaborate the last two aspects; more investigation is required on these two aspects.

4.2 Working method in practice

The five sub-phases of the problem diagnosis are elaborated.

1. Justification of the investigation
The reasons to investigate the return flows are:

- Within the TQM-plan, it is necessary to monitor and control the return flows.
- It is necessary to design a concept for the control structure of the return flows, to achieve zero stock for non-kitted spare parts in the European NSO's. An integral approach of the control of return flows will result in a decreased amount of stock in the integral chain which results in lower inventory costs.
- As a result of the environmental legislation in the future, the return flows of recyclable and reusable products need more attention.

2. Problem formulation
Considering the return flow characteristics and financial aspects, design a concept for the control structure of the return flows and design performance indicators to measure the performance of the return flow process.

3. Knowledge/understanding gathering
In literature the knowledge about return flows is focused on repairables. The available information about repairables mostly regarding descriptions of queuing models from the Operations Research discipline.

For a better understanding of the qualitative and quantitative aspects of the return flows, a pilot study is executed. A lot of people, involved with the return flows, are interviewed and processes, procedures and working methods are analysed. The pilot study results in the description of the logistic characteristics of the service and repair process (see section 5.1), and in the description of the existent control system (see section 5.2).

4. Problem analysis
The information gathered in sub-phase three is further analysed. All elements and aspects of the problem be made more explicit, are further specified and when possible are related to each other; resulting in a clear-cut problem definition. In the problem analysis the distinction is made between problem symptoms and the real problems. The problem analysis is shown in section 5.3. In this section only the problems concerning the flow of repairables are described. For more detailed information about the problems concerning the other return flows, see the intermediate report.

5. Demarcation
Given the expected costs savings, the expected customer satisfaction improvement and the available time, only the flow of repairables is analysed in further detail.

Chapter 5 Logistic characteristics and problem analysis

The logistic characteristics of the IE service and repair process are described in section 5.1. Information is given about the customer requirements, the product characteristics and the process characteristics. The description of the existent control system, which coordinates the logistic activities concerning the flow of the repairable spare parts, is mentioned in section 5.2.

The existent way of organization and control of the flow of the repairable spare parts causes some problem. The problem symptoms and causes are described in section 5.3 and finally the problem definition is given in 5.4.

5.1 Logistic characteristics of the service and repair process

The OC's of IE provide standard and custom made products, systems, projects and services for professional markets, all over the world. The products, systems and projects are developed and manufactured within the Supply Centre of the OC. In the countries, the NSO is responsible for the sales and service activities.

In order to guarantee the customers the required 'system uptime', spare parts are stocked. The total supply chain of spare parts includes: the Philips Supply Centres and the external suppliers (the suppliers of the spare parts), Philips Consumer Service (PCS) as the central stock point, the national warehouses from the National Sales & Service Organizations (NSO), the field service engineers and the customers. The spare parts are delivered from PCS to the countries (NSO's). For some countries however, direct delivery from PCS to the service engineers, or even the customers, is possible.

In general, for the IE business, the OC's have delegated a part of the logistics of their service operation to PCS. The Logistic Operation of PCS is responsible for warehousing and distribution of the spare parts. For the IE spare parts, the OC's are financially responsible for the stock level.

The spare parts can be divided into non-repairable and repairable spare parts. Many parts are thrown away if they are diagnosed as defective, other parts, the most valuable ones, are repaired after they have turned defective. *Repairables are defined as durable items determined by economic and other factors, to be restorable to serviceable condition through regular repair procedures.* A spare part is selected as a repairable spare part considering the following criteria: new-price of the part, repair costs, technical lay-out of the part, obtainability of the part and obtainability of the repair tools and test equipment. The decision whether a part is a repairable part is taken by the service department of the OC. The service department also determines the repair price and the repair location.

The repairable spare parts are participating in one of the following repair circuits:

1. Field service repair circuit
Every NSO has a number of field service engineers supporting service activities at the customers' site. The following service activities can be considered: cleaning of the installations, adjusting of the software, small repairs and the replacement of field exchangeable parts. These parts need to be repaired in the local/regional workshop of the NSO or in the factory of the supplier. From now on, the term Repair Centre is used when the factory of the supplier is the repair location.

2. Local or regional repair circuit
Some field exchangeable units can be repaired locally in the NSO workshop or in a regional workshop. Others have to be repaired centrally, in the Repair Centre, because high investments may be involved in local repair, some specialized technical knowledge may be required, or the necessary repair tools and test equipment are not available.

3. Central repair circuit with intervention of PCS
PCS has a repair procedure for defective repairables. The PCS repair procedure is an exchange procedure; the NSO contacts the Customer Relation department at PCS in order to get a repair authorization. After the request of the repair number PCS sends a new/repaired part to the NSO. PCS invoices the NSO with the new price of the part. The NSO has to return the defective part to PCS. After receipt at PCS, the NSO gets a credit note for the defective part against the return price. The return price is equal to the price of the new/repaired part (within PCS defined as the key price) minus the customer repair price. The customer repair price amounts to about 30 % of the new price of the part.
The defective parts are checked visually and stored in a warehouse for defective stock. Weekly the inventory control system at PCS generates repair orders. The defective parts will be picked and shipped from PCS to the Repair Centres.

4. Central repair circuit without intervention of PCS
Some OC's (Power Systems, Professional TV test equipment and Industrial X-ray) have organized their repair process without intervention of PCS. Defect repairable parts are shipped from the countries directly to the Supply Centre of the OC for repair. Some OC specific repair procedures without intervention of PCS are described in appendix 4.

The flow of the repairables and the repair circuits are visualized in figure 5.1. From figure 5.1 it becomes clear that a repairable part can be characterized as a cycle part. The status of a cycle part can be: still in use in the installation, available in the new/repaired stock, available in the stock of defective parts, in repair at the workshop or the Repair Centre and on transport. More detailed information about all IE goods flows and the description of the entities, involved in the goods flow, is given in appendix 1.
From this point onwards the investigation is focused on the central repair circuits; in the assignment is defined that the return flows in case of central repair has to be analysed. Especially the central repair circuit with intervention of PCS is described, because most OC's make use of the PCS repair procedure. The central repair circuit without intervention of PCS is not described here, because this circuit is OC specific.

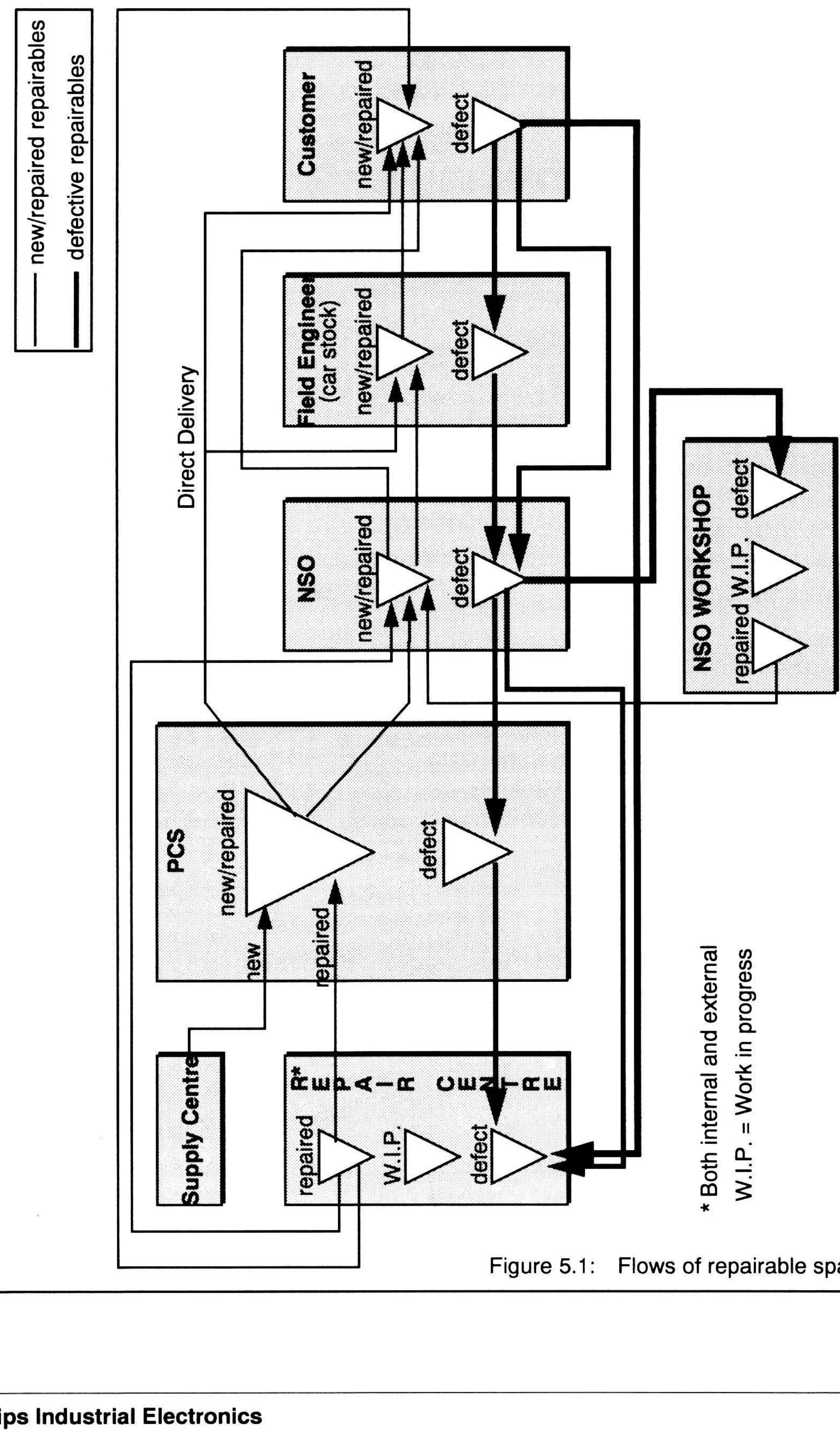


Figure 5.1: Flows of repairable spare parts

The basic structure of the IE integral spare parts chain with intervention of PCS is depicted in figure 5.2 on next page. All activities concerning the flow of repairables are visualized by flow charts. The flow charts are shown in appendix 2.

The value of the goods movements and the stock levels are also depicted in figure 5.2. The division of the value of the goods movements and the stock levels per OC is mentioned in appendix 3.

The market, product and process characteristics concerning the above mentioned central repair circuit with intervention of PCS are described now. The characteristics are the input factors for the determination of the optimal logistic structure and the control system.

5.1.1 Market characteristics

The most important design parameters for the design of the basic structure are the market (customer) requirements concerning service and repair aspects. The service and repair specific requirements are described in this sub-section. If possible, some OC specific information is given to quantify some requirements. The agreements concerning service actions between the NSO and the customers are mentioned in service contracts. Agreements are made about the following subjects:

- Response time/reaction time: the time required between the receipt of an order or impulse triggering some action and the initiation of the action [2]. The average service response time for the OC Electron Optics in most countries is two working days (Source: Service Marketing Plan for Transmission Electron Microscope).
- Availability of spare parts and repair obligation during the service period. The length of the service period is in general between the five and ten years.
- Repair leadtime of customized repairable spare parts (in case of customized parts the customer wants his own article back after it has been repaired). The OC Power Systems has agreements with some customers about a repair leadtime of two weeks.

The demand pattern of the IE spare parts is irregular and unpredictable; the moment an installation fails is unknown. When the NSO's order spare parts, they usually order one piece or a small batch size of one repairable code number. The delivery time of spare parts from PCS to the NSO's is between the one and five days.

The customers want one Philips 'front door' in their country. The added value of the NSO in the central repair circuit is:

- Front line communication with the customers. The customers want the telephone answered in their own language and the customers want to know the person they are talking to and this person has to know them.
- The NSO can execute the logistic and administrative activities concerning the return shipments of defective parts to the Repair Centre. The OC Power Systems has organized the repair process without the intervention of the NSO; the customers have to ship the defective parts directly to the Repair Centre. The customers are not satisfied about the direct repair procedure. The customers want that Philips organizes the return shipments of the defective parts to the Repair Centre. The results of some executed customer interviews are described in appendix 5.

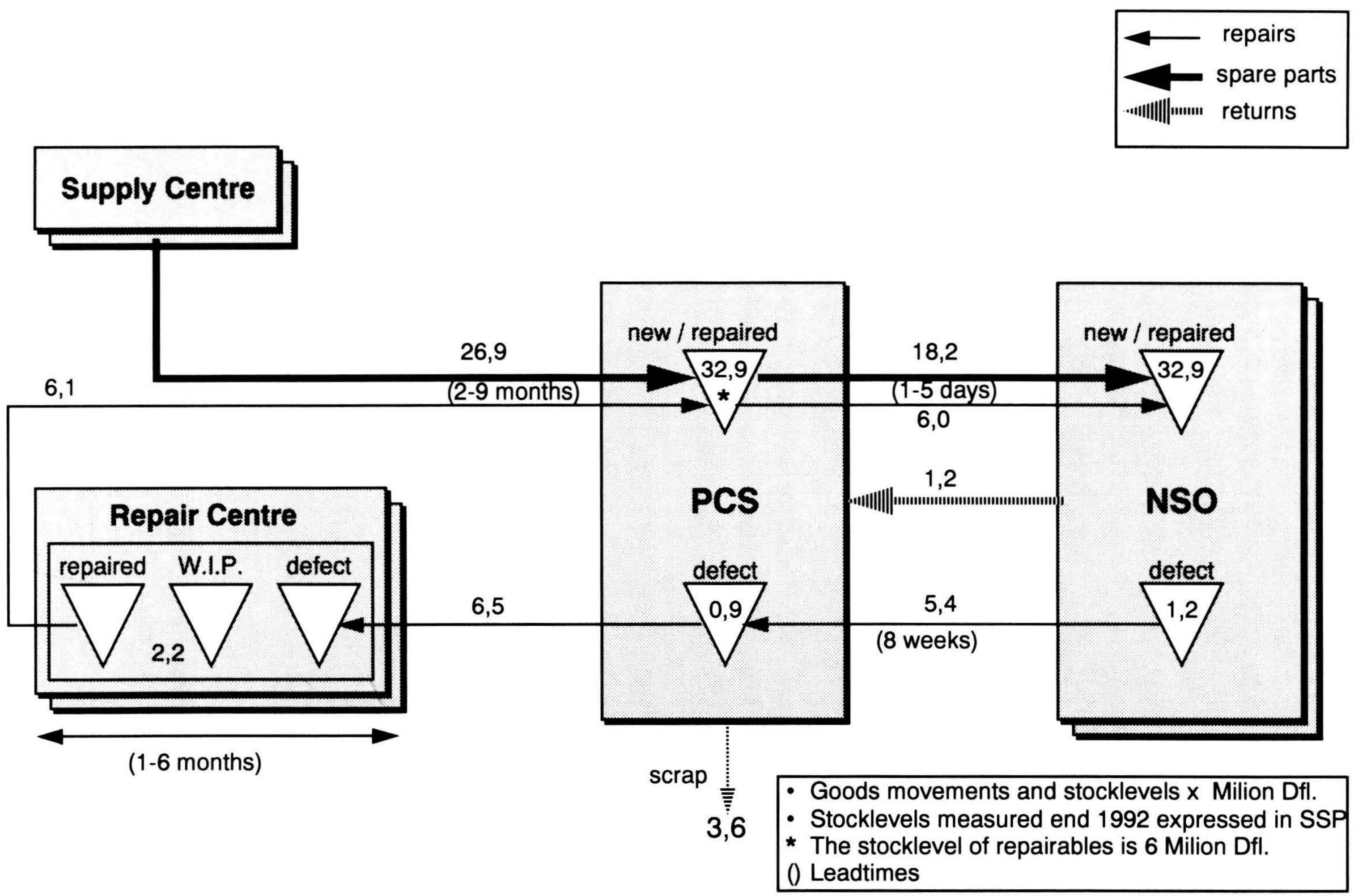


Figure 5.2: Goods movements and stock levels of spare parts

Within TQM there is a drive for continuous improvement of the customer orientation. The IE Holding has contracted NIPO, the Dutch Institute for Perception Research, to carry out a customer satisfaction survey, laid down in appendix 6. The results from the NIPO survey regarding customer service are that in general, for all OC's, the customers are satisfied about the response time, the repair leadtime and the availability of the spare parts. But not all customers are satisfied concerning customer service aspects. The aspects regarding customer service with 10% or more dissatisfied customers are: meeting delivery dates, repair leadtime, availability of spare parts and value for money in customer service.

5.1.2 Product characteristics

Within this sub-section information is given about the number of spare parts and repairables, and the different existing repair indicators in the PCS repair procedure.

The number of service type numbers (service 12 NC's) for IE stocked at PCS amounts to 44.177 different spare parts (29-12-1992). All parts are categorized in Issue Frequency Groups (IFG). The IFG indicates to what extent an article is slow or fast moving, see appendix 7. About 90% of these parts are slow-moving items; the orderline frequency (customer orders) of these items amounts to 0 - 4 orderlines per year. The reason for the large amount of slow-movers is caused by the length of the service periods and the low demand during the service period.

The number of repairable service type numbers for IE controlled at PCS are 1720 of the 44.177 service 12 NC's.

A spare part that participates in the repair procedure of PCS, has one of the following repair indicators (repari):
Normal repair (repari 1); this article can either be obtained as a new part or exchanged via the repair procedure (also called the exchange procedure).
Customized repair (repari 2); the NSO gets his own article back, after it has been repaired. The part number is not available as a new part from PCS. This repair is code number dependent.
Future dead article (repari 3); existing transactions will be settled, but no new requests will be honoured.
Coupled repair (repari 4); the customer wants to be 100 % sure that he gets his original part back after repair. This repair is transaction dependent repair.
Only repair (repari 5); this article can only be exchanged via the repair procedure (also called the exchange procedure), it cannot be obtained as a new part.

About 90% of the repairable spare parts have repair indicator 1 or 5.

5.1.3 Process characteristics

The characteristics of the return process of defective spare parts from the countries to PCS, the repair process, and the delivery process of new/repaired spare parts from PCS to the NSO's, engineers or customers are mentioned in this sub-section. Information about process leadtimes are shown in figure 5.2 (page 13).

Return process
The return time of a defective part from the NSO to PCS is long and unreliable. Within the inventory control system the value of the average return time is 8 weeks. The exact value of the average return time and the deviation is unknown, because no performance measuring exists.

Repair process

The repair process of customized (repari 2) and the coupled repairs (repari 4), is typified as a "repair to order" situation; the customer wants his own original part back after repair. The repair process of the normal (repari 1) and the only repairs (repari 5), is typified as a "repair to stock" situation. The repair procedure in case of normal and only repairs is an exchange procedure: the NSO receives a new/repaired part from PCS, and returns the defective part to PCS. The repair batch size is mostly one piece.
The delivery performance of some Repair Centres is low; the reliability of on time deliveries is not high. The delivery performance of the EO Repair Centres to PCS is 56% (see appendix 15).

Delivery process

The delivery performance for IE spare parts from PCS to the NSO's is approximately 80%, while the PCS target is 95%.

5.1.4 Conclusion

The consequence of these characteristics, the short requested customer delivery times compared with the long repair and production leadtimes and the irregular demand pattern, is that all the non-repairable spare parts and the non-customized repairables must be kept in stock to guarantee the customer the required 'system uptime'. The stock is a sort of flexibility to tackle the uncertainty in the demand. Because general service characteristics are so conflicting (short delivery times versus long production and repair leadtimes, low unpredictable demand and long service periods), the risk of being obsolete is extremely high: about 60% of the total stock, see appendix 3.
In case of customized repairs the uncertainty in the repair demand cannot be tackled with stock. The only way to satisfy the customers is to realize short and reliable repair leadtimes. Short and reliable repair leadtimes can be realized when the available man and machine capacity is big enough or when the possibility of a fast capacity increase exists.

5.2 The existent control system

A control system indicates how decisions regarding goods flows and capacities are taken.
Concerning the *capacity aspect*, agreements exist about the availability of man and machine capacity, during the service period. The agreements are made between the service department of the OC and the Repair Centre.
But no agreements exist between PCS and the Repair Centres about the expected number of repairs during a year, the frequency of repair and the average batch size per repair order. Because the Repair Centre does not know the number of expected repairs per annum it is impossible to reserve man and machine capacity for repair activities. The lack of capacity reservation causes long and unreliable leadtimes.
When agreements are made about the number of expected repairs per annum, the average batch size and the frequency of repair, it is possible to make an expectation about the required number of man and machine capacity hours (Given the expected number of repairs per annum and the repair times within the Repair Centre, the number of required capacity hours can be determined). With the help of this information capacity must be reserved. Capacity reservation for repair activities will result in shorter and more reliable repair leadtimes.

Concerning the *material aspect*, the inventory of the repairables is controlled by a BQ system. When the economic stock undershoots the reorder level (B) an order of quantity (Q) is placed at the supplier.
In the ordering procedure of a repairable part, two reorder levels are distinguished: the repair level (R-level) and the reorder level for new parts (B-level). With the help of the R-level the stock of new/repaired parts at PCS has to be controlled. The R-level indicates the number of new/repaired parts that must be available at PCS to cover the average demand during the repair leadtime and to cover the greater than average repair leadtime demand which occurs from time to time.
When the economic stock drops below the R-level, a repair order will be released to the Repair Centre to replenish the stock of new/repaired parts at PCS. The economic stock of new/repaired repairables is equal to: Physical stock + Repair balance + Customer return balance - Backorder balance - Reserved order balance - Order balance still to be reserved.
Within PCS the R-level is determined with the following formula:

$$\text{R-level} = 0.75(P_t + P_{tr})$$

P_{tr} = repair consumption forecast for the next year; the forecast of the number of parts ordered by the NSO's within the repair procedure. (The NSO returns the defective part to PCS)

P_t = normal consumption forecast for the next year; the forecast of the number of parts ordered by the NSO's without the repair procedure. (The NSO returns no defective part to PCS)

With the help of the B-level the integral stock of defective and new/repaired parts in the entire chain (repair pool inventory level) has to be controlled. For a repairable spare part the repair pool consist of: the new/repaired parts which are located at PCS, the defective parts which are located at the NSO's and at PCS, the parts in the pipeline and the parts in the Repair Centre for repair (see figure 5.1).
The B-level indicates the number of defective and new/repaired parts that must be available in the entire chain (Repair Centre, PCS, NSO's and Engineers) to realize the required availability degree of spare parts to the customers.
When the economic stock of parts in the entire chain (repair pool inventory level) drops below the B-level, new parts have to be ordered at the Philips Supply Centre or at the external supplier. The ordering of new parts is necessary when defective parts are not returned from the NSO's to PCS, or when defective parts are irrepairable because the failure cannot be solved. The economic stock of repairables in the entire chain is equal to: Physical stock + Supplier order balance + Repair balance + Customer return balance + Unrepaired stock + Customer repair return balance - Backorder balance - Reserved order balance - Order balance still to be reserved.
Within PCS the B-level is determined with the following formula:

$$\text{B-level} = \frac{P_t * L}{52} + \frac{P_{tr} * R_{tt}}{52} + SS$$

L	=	Leadtime in case of purchase orders
R_{tt}	=	repair transaction time (rpktime + reptime)
rpktime	=	return time from the NSO to PCS
reptime	=	repair leadtime
SS	=	safety stock

The formula of the safety stock is:

$$SS = f_v * 0.5 * \sqrt{(1 + 0.2188 * L * P_t^{1.54})}$$

f_v is dependent on the availability degree of spare parts. If the availability degree is 95 %, then f_v = 0,85 (Source: IE service parts management guide).

5.3 Problem analysis

The assignment, defined in chapter 3, has to be made more explicit and must be further specified, resulting in a clear-cut problem definition. During the analysis of the flow of repairables and the existent control concept, a number of problem symptoms have been signalized. When possible, the underlying causes of the symptoms are mentioned and if possible be quantified. The problems related to the PCS repair procedure are mentioned in this section. The main problems concerning the inventory control system used by PCS (treated in sub-section 5.3.1) and the long and unreliable leadtimes in the repair loop (see sub-section 5.3.2). Both problems cause high stock levels in the entire chain and too high stock-out risk. The high stock levels result in high inventory costs and the high stock-out risk results in a low service performance to the customer and thus a low customer satisfaction. Further on problems exist regarding working methods of the service engineers and the way the NSO's use the PCS repair procedure. These problems are handled in sub-section 5.3.3.

5.3.1 Problem analysis regarding the inventory control

Concerning the within PCS used inventory control system the following problems are signalized:

- There exists no integral inventory control of new/repaired parts in the entire chain. A local order point method is used. Each link in the chain orders at the next higher link. The lack of coordination between the separate links results in that each link keeps safety stock to cover the uncertainty in demand and leadtime variation.
- There is no time-phased available balance computation, because the scheduled receipts (supplier order balance repair balance, customer return balance and the customer repair return balance) are not time phased. The lack of time-phased available balance computation causes unnecessary ordering of new parts, while enough parts are available in the entire chain.
- The repair level (see section 5.2) is too high and not leadtime related. In the past the R-level was determined from experience with the underlying theory that all defective parts had to be repaired as soon as possible. There exists no theoretical foundation for the determination of the repair level.
- The return time from the NSO to PCS is code number dependent, but has to be NSO dependent.
- The safety stock formula was determined in the past. The derivation of this formula is unknown. Within this formula only the variation of the leadtime and the variation of the average demand during the average leadtime are considered. In case of the control of repairable parts also the variation of the repair transaction time and the variation of the average repair demand during the average repair transaction time has to be considered.
- The safety stock formula is used for all Issue Frequency Groups (IFG). The IFG indicates to what extent a spare part has a slow or fast moving character. In case of parts with a slow moving character, the variation of the average demand during the average leadtimes, related to the average demand, is higher than in case of fast moving parts.

5.3.2 Problem analysis regarding the leadtimes

The existent return times of the repairables from the NSO's to PCS and the repair times in the repair centres are long and unreliable.

Return times from the NSO's to PCS
The value of the defective repairables still to be received from the NSO's (the customer repair return balance; for these parts a repair authorization number exists) amounts to Dfl. 1,2 million expressed in Standard Stock Price (SSP), shown in figure 5.2. The total value of the defective repairables returned from the NSO's to PCS, in 1992, amounts to Dfl. 5,4 million expressed in SSP. Roughly estimated can be stated that the average return time is about 12 weeks (customer return repair balance value divided by the customer return value in 1992).
In the PCS repair procedure it is mentioned that PCS has the right to cancel a repair transaction if the defective repairable has not arrived at PCS within two weeks for transactions within Europe and four weeks for inter-continental transactions after PCS has issued the repair number to sender.
The above mentioned guide-lines are not handled in reality. A short investigation was carried out to show the current situation with regard of the returns of defective repairables, see table 5.1.

Table 5.1: The % of the defective repairables not arrived at PCS, on 27-04-93, within the in the PCS repair procedure mentioned determined time.

Countries	% of the defective repairables not arrived at PCS within two weeks
Netherlands	56
Great Britain	60
Germany	58
France	33
USA (For the USA the time interval is four weeks)	56

The causes for the long and unreliable return times are:

- No control of the return flow of the repairables. No real targets exist (the PCS guide-lines are not used in reality), there is no performance measuring and no penalties exist when the defective repairables have not arrived at PCS within the determined time frame.
- Unambiguity about the responsibility of claiming on the NSO's, when the defective parts have not arrived at PCS within the agreed time frame. Is the repair department of PCS or the customer relation department of PCS responsible for claiming on the NSO's?
- Lack of notice, within the NSO's, about the importance of a fast return shipment from the NSO's to PCS. The NSO collects the repairables and ships the defective repairables in batches to PCS. The reasons why are to decrease the transport costs and to decrease the preparation time of the transport documents and delivery notes.
- Within the NSO's a lack of control of the return flow from the service engineers to the NSO's exist. There are no targets, there is no performance measuring and no penalties exist when service engineers have a bad return performance.
- Lack of notice by the service engineers about the importance of a fast return shipment.

Repair times
About 45% of the receipts of repaired repairables, from the Repair Centres, at PCS are not delivered within the agreed repair time (Source: PCS). In december 1992 the value of the outstanding repair balance with the Repair Centres amounts to Dfl. 2,2 million expressed in SSP, see figure 5.2. The total value of the repaired repairables returned from the Repair Centres to PCS, in 1992, amounts to Dfl. 6,1 million expressed in SSP. Roughly estimated can be stated that the average repair time is about 19 weeks (repair balance value divided by the value of the repaired repairables from the Repair Centres to PCS).

The long and unreliable repair times are caused by:

- No agreements exist about fixed repair times and average batch sizes of repair orders between PCS and the Repair Centres.
- Not all suppliers of repairable spare parts have a separate repair shop. The result is that capacity has to be reserved in the regular production process for the repair of defective parts. When the utilisation degree of the production process is high, problems occur when capacity has to be reserved for repair orders.
- Low priority of PCS repair orders in the Repair Centre's; the repairables located at the Repair Centre are uncharged.
- Only performance measuring exists dealing with the number of parts delivered within the agreed repair time, but no performance measuring exist concerning average repair times and the variation.
- The absence or the incompleteness of a complaints description causes delay in the repair process. In about 60% of the shipments from the NSO's to PCS, the NSO does not send a complaints description or an incomplete complaints description. The result is a longer leadtime of the repair process. The absence or the incompleteness of a complaints description is caused by not enough attention/motivation by the engineers to fill in a complaints description.

5.3.3 Problem analysis regarding the way the NSO's use the PCS repair procedure and the working method of the service engineers.

About 25% of the repairables shipped from the NSO's to PCS are not defective.

Two causes can be distinguished:

- Field Service Policy: more and more the field engineer only replaces modules (e.g. boards) without testing and repairing them. The engineer is not able to diagnose the failure, because the engineer does not have the necessary tools and test equipment. With the result of the advanced technology used by the production of the modules, the needed tools and test equipment are very expensive and therefore located at the Repair Centres or at the Supply Centres.

  Misuse of the repair procedure: The NSO has no repair request of a customer, but contacts PCS to get a repair number. PCS delivers a new/repaired part to the NSO but the NSO ships no defective part to PCS (at the moment no defective part exists). The NSO uses this part as safety stock. When no demand for the part exists, during the service period, the NSO ships the part (not defective) back to PCS.

In the NSO's defective repairables (no repair number is requested) are stocked. The stock value of defective repairables located at TSPA (the Dutch service organization for IE services) amounts to about Dfl. 50,000.= expressed in SSP. The causes are:

- No structured procedure exists for the return shipments of defective repairables (no repair number is requested) from the NSO's to PCS. The NSO cannot return the defective repairable without ordering a new one. When the NSO has some defective parts and some new/repaired parts, the NSO does not request a repair authorization number (because the NSO is obliged to buy a new/repaired one with the result that the stock of new/repaired parts will increase at the NSO).
  Insufficient use of the repair procedure: The NSO orders new parts without the use of the PCS repair procedure. Later on the NSO realizes that the defective parts can only returned if a repair number is requested. So the NSO stocks the defective parts until the NSO needs new/repaired parts.

Field service engineers do not ship the defect repairables, via the NSO, to PCS but contact some engineers at the Repair Centres to repair the defective repairables. This informal channel is used because the total leadtime of the repair process via PCS is too long given the customers requirements.

5.4 Problem definition

According to the results of the problem analysis, the problem is defined in this sub-section.
The results of the problem diagnosis phase is that the existing control method causes the following problems:

- long and unreliable leadtimes; tardiness exists in about 50% of the goods movements of the return flows from the NSO's to PCS and tardiness exists in about 45% of the goods flow of repaired parts from the Repair Centres to PCS.
- high inventory levels in the entire chain; amongst others caused by the lack of integral inventory control in the entire chain and the long and unreliable leadtimes.
- the delivery performance of PCS concerning IE spare parts is 80%, while the target is 95%.

The main causes are the lack of agreements concerning the return times from the NSO's to PCS, the lack of agreements with the Repair Centres, the incorrect inventory control, the lack of logistic organization and the absence of a performance measuring system.

In order to realize a higher customer satisfaction by decreasing the integral logistic costs, the existent way of control has to be improved. Four steps are taken to improve the control of the flow of the repairables. The first and most important step is the simplification of the existent basic structure. With a simplified basic structure the leadtimes and the leadtime variation can decrease. The determination of the basic structure is described in chapter 6.
In chapter 7 the design of the control concept is described. Within this concept the most important part are the agreements between the entities dealing about the leadtimes.
After the defining of the basic structure and the control concept, the third step considers the agreements about tasks and responsibilities.
The last step is the measuring of the performance. The logistic organization and the performance measuring are also described in chapter 7.

Chapter 6 Basic structure of the IE service and repair logistics

Within the design of the integral logistic control structure, the determination of the basic structure is important. The basic structure reflects the structure of the goods flow through the entire supply chain. The choice of the basic structure is a long term decision, a structural trade off. The basic structure sets the conditions for the daily operational activities so that the operational goals, high customer service level and low integral costs, can be realized. The control complexity will decrease when the complexity of the basic structure decreases. Hoekstra & Romme [6] describe: 'a simple basic structure is an important organizational condition for a good logistic control'.

Before the basic structure is handled, the objectives are defined. In general the following logistic objective concerning the production activities can be formulated: Improve the customer service level by decreasing the integral costs (Source: Brevé [3]). The customer service can be improved by a decrease of the leadtimes, delivery performance improvements and an increase of the flexibility.
Concerning the service and repair logistic within PCS the following objective is formulated: Availability of spare parts during the service period with a delivery performance of 95%.
The repair objective is formulated as minimise the customer servicing costs by recirculating expensive parts. A defective part that has been returned to PCS for repair, will be upgraded to the specifications of the latest version, against about 30% of the new price of the part, within the agreed time frame.

The existing basic structure of the IE integral spare parts chain is depicted in figure 5.1. Figure 5.1 shows a complex basic structure; many stock points and a shared resource (PCS) exist. In determining the most optimal basic structure, the existing complex structure has to be simplified. The objective is to decrease the number of stock points and shared resources given, the customer requirements and the integral costs.
In determining the basic structure of the logistics of repairable spare parts, two topics are important: the repair capacity structure and the inventory structure of spare parts. These structures are determined, given the customers' wishes, the product and the process characteristics, as described in see section 5.1.
First, the repair capacity structure has to be determined, see 6.1. The repair capacity structure sets conditions for the inventory structure; the locations of the repair centres influence the inventory structure of the defective parts. After the description of the repair capacity structure, the inventory structure of the new/repaired parts is described in section 6.2 and the inventory structure of the defective parts in section 6.3.

6.1 Repair capacity structure

The repair capacity structure reflects the locations of the repair centres. Two main basic repair structures are possible.
Local repair in each country. The defective repairable parts are repaired in the NSO workshop. The NSO has to invest in repair tools, test equipment, spare parts stock, and training of the service engineers.
Central repair. The defective repairable parts are repaired in the factory or in the repair shop of the supplier.

Given the objective of a high customer satisfaction, realized against minimal costs, the final repair capacity has to be determined. The design parameters defining the repair structure are described in 6.1.1. The repair capacity structure choice is described in 6.1.2.

6.1.1 Design parameters

The decision whether a part should be locally or centrally repaired is dependent on the main design parameters the customer requirements and the integral costs.

Customer requirements
Concerning the customer requirements regarding repair activities, three aspects are distinguished: quality, time and price.
Concerning the *quality aspects*, the customer wants a minimal mean time between failures, so the repair quality is very important. In general the repair quality of central repair in the factory is higher than in that of local repair in the NSO workshop. In the factory the most advanced repair and test equipment are available and the engineers are more experienced, because the frequency of repair of a certain product type is higher, so the experience of repair will increase (specialization).
With respect to the *time aspect*, the division in customized repairs and non-customized repairs is made. In case of customized repairs, the customer needs the repaired part back within an agreed repair time. The agreed leadtime is a compulsory design parameter for the repair capacity structure. If a short repair time is requested and the repair throughput time of central repair is too long, then the parts have to be repaired locally. Otherwise, the integral costs, design parameter two, are decisive by choosing the repair structure. In case of non-customized repairs the customer wants a new/repaired part delivered from stock; the availability of new/repaired parts is important for the customer. The location of the Repair Centre is not important at all from the customers' point of view. In case of non-customized repairs the integral costs are decisive by choosing the repair structure.
Concerning the *price*, the customer wants value for money in customer service, see NIPO research appendix 6.

Integral costs
An important parameter in appointing the costs level is the annual repair demand per country. Four cost types are distinguished.
Transport & Handling costs. The transport costs consist of a fixed part per shipment (independent of the number of parcels) and a variable part per kilogram. The transport costs are dependent on the annual repair demand per country, the distance between the NSO's and the central repair shop and the weight of the products. In case of local repair the transport costs are lower than in case of central repair.
Manpower costs. The manpower costs are dependent on the workload (number of repairs in a year). In case of a high workload the service engineers get skilled in repairing repairable parts. The repair time per repairable will decrease when the workload increases. This phenomenon can be explained by the so called "learning curve". The repair time decreases with a certain percentage if the accumulated number of repairs is doubled. In case of local repair the manpower costs are higher than in case of central repair.
Investment costs in equipment and training. To repair and test the repaired parts the OC's need to invest in repair tools, test equipment and the training of the engineers. Given the investment costs, the duration of life, the service period and the number of repairs, the investment costs per repair can be measured. In case of central repair the investment costs are lower than in case of local repair; repair tools and test equipment are available at one location, with the result that less investments are required. The mechanization for tracing defects becomes more economical, because of a good degree of utilization of personnel, equipment and tools.

Inventory costs. Two different types of inventories are distinguished. First, the stock of spare parts needed to repair the repairable parts. In case of local repair, in each country spare parts have to be stocked. When the repairables are repaired in the factory or in the repair shop of the supplier, one stock point of spare parts is enough. Second, the repair loop inventory stock of repairables. In case of local repair, every NSO has a safety stock of repaired parts. In case of central repair, only one safety stock of repaired parts exists. Especially for slow-moving parts with a high money value, it is preferred to stock the parts on one location, given the high risk of obsolescence.

6.1.2 Repair capacity structure choice

Per design parameter it is indicated which repair structure is preferred, see table 6.1.

Table 6.1: Local or central repair.

Design parameter	Local repair	Central repair
Repair Quality		+
Repair time	+	
Transport & Handling costs	+	
Manpower costs		+
Investment costs		+
Inventory costs		+

The local repair strategy has to be chosen, when the local repair quality is equal to the central repair quality and the repair time of customized repairs, in case of central repair, is too long compared with the with the customer agreed repair time. The local repair strategy has also to be chosen when given the repair demand, the total integral costs concerning local repair are lower than the total integral costs in case of central repair.

The central repair strategy has to be chosen, when the with the customer agreed repair time in case of central repair can be realized and when the total integral costs in case of central repair are lower than the total integral costs in case of local repair.

6.1.3 Conclusion

For the IE business it is in general preferred to repair centrally, because:

- the total repair demand is low; from the 1720 IE repairables within the PCS repair procedure approximately 90% have a slow-moving character (sub-section 5.1.2). Given the total repair demand, the repair demand per country will be much lower.
- technological changes leading to advanced production methods cause high investment costs of tools and equipment.
- faster and more frequent transport; the turnaround time in case of central repair is no problem.
- decreasing transport costs.
- a closed quality loop can be realized; the production department is confronted with the product failures. In case of central repair, it is easier to register all the product failures. The registration of the failures (quality reporting) can be used for feedback to the design, production and sales department. When quality reporting is used a process of continuously quality improvement is set into motion. In case of local repair the realisation of a closed quality loop causes some organizational problems; activities have to be coordinated and communication problems can occur.

The validity of the statement mentioned on the previous page has to be tested for every OC, but from this point in the report onwards the assumption is made, based on the above mentioned reasons, that repairable parts are repaired centrally.

More detailed information about the optimal repair structure is described in the report 'Towards a centralised Test & Measurement customer support set up' written by Martens [8].

6.2 Inventory structure of new/repaired spare parts

Two inventory structures can be distinguished: the inventory structure of the new/repaired spare parts, described in this section, and the inventory structure of the defective spare parts, discussed in section 6.3.

For the IE business, spare parts are stocked at several stock points based on anticipated demand. These points are:

- Supply Centre. Some OC's stock the spare parts in their own Supply Centre and not at PCS (e.g. Power Systems in Wavre). Other OC's stock spare parts in their own Supply Centre and also at PCS (e.g. Electron Optics in Acht).
- PCS.
- National Service Organization.
- Car of the service engineer.
- At the customers' address, where the customer is owner of the spares.

The final allocation decision is dependent on the customers' needs and the total of the inventory ownership costs, the expected shortage costs and the transport costs.
The spare parts supply policy of IE is to achieve zero stock of non kitted spare parts in the NSO's. This means a shift of the Customer Order Decoupling Point (see appendix 8), from the national stocks to the central stock in Eindhoven. In order to make this possible, acceleration of the logistic process (ordering spare parts, material handling in the central warehouse and physical distribution) is necessary. At the moment Direct Delivery, the delivery of spare parts from PCS to the service engineers or even to the customers, is implemented for Germany, United Kingdom and France (partial). For the organization of the return flows of repairables it is very important that direct delivery is executed very well; a high delivery performance has to be realized. When direct delivery is not reliable, the NSO's will stock repairable parts. When the NSO's have a stock of new/repaired parts, they only return the defective repairables when they need new/repaired parts. So, not reliable direct delivery causes delay in the return process of defective parts.

At the moment a stock down project is running. The objective is to decrease the stocks in the NSO's. From this point in the report onwards, no further attention is paid to the inventory structure of the new/repaired spare parts; this is no part of this project.

6.3 Inventory structure of defective spare parts

The total stock of defective repairables is located at different stock points in the entire integral chain. The possible locations are depicted in figure 5.1. Beside the inventories in the stock points, pipeline inventories exist. The pipeline inventories exist of defect repairables, which are transported between some entities. The functions of the inventories are mentioned in table 6.2.

Table 6.2: Functions of the inventory.

Stock points	Function of the inventory
Customer	Stocks of defect repairables at customer's site have no function.
Engineer	Carstocks of defect repairables have no function. The field engineer has to return the defective repairables to the NSO or the central stock point of defective parts as soon as possible.
NSO	The NSO batches defect repairables. It sends a batch of defect repairables to PCS; not every item is shipped separately to PCS. The reason for this is to decrease the total of handling and transport costs in a period.
PCS	The stock at PCS is a buffer stock. PCS stores defect repairables until a repair order is generated in the Inventory Control System.
Repair Centre	The defect repairables transported from PCS to the Repair Centres, are stocked at the Repair Centres until there is man and machine capacity available to start with the repair order.

In determining the inventory structure of the defective repairable parts, two parts of this structure are distinguished. At first the *return process* from the country to the central stock point and at second the central *collecting process*.

For both parts, three strategies are possible. The design parameters, determining the final strategy choice, are mentioned in 6.3.1 for the return process and in 6.3.2 for the collecting process. Given the three possible return strategies and the three possible collect strategies, twelve logistic structures are possible, see figure 6.1.

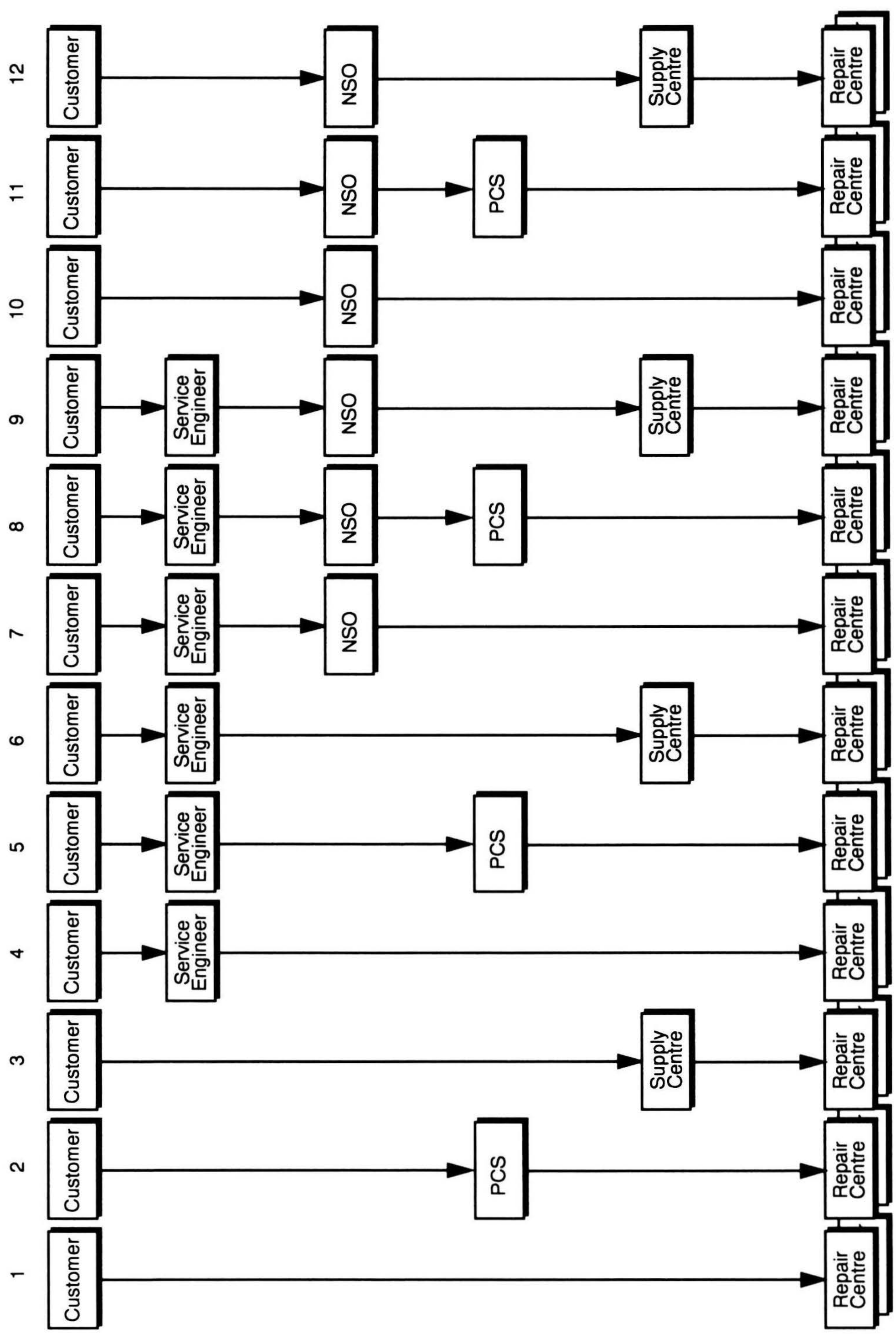


Figure 6.1: The possible logistic structures

6.3.1 The return process

In case of central repair in the Repair Centres, there are in general (not for all OC's) three possible strategies to return the defective parts to the central stock point of defective parts.

Strategies
1. *Customer returns the parts to the central stock point.* When the customer is able to replace the repairable part himself, it is possible to organize a return flow without the intervention of the service engineers and the NSO's. For example, the OC Power Systems made a new repair procedure; the customers have to ship the defective power supplies to Wavre (B) without intervention of the service engineers and the NSO.
2. *Service engineers return the parts to the central stock point.* The geographical spread of the customers is an important parameter in determining the inventory structure. Large geographical spread requires extra attention to the delivery of defective repairable spare parts from the field service engineers to the NSO or to the central stock point. Field service engineers who visit the NSO less than once a month, have to ship the defective parts directly, without intervention of the NSO, to the central stock point.
3. *NSO's return the parts to the central stock point.* When the service engineers (or the customers) deliver the defective parts to the NSO, the NSO returns the defective parts to the central stock point.

The final way of organizing the return flow structure in each country is dependent on the following design parameters.

Design parameters
Replaceability of the repairable part by the customer. Is a service engineer needed for the replacement or can the customer replaces the part himself? If the customer cannot replace the defective part strategy one is impossible.
The *customers want one Philips 'front door'* in their country (see sub-section 5.1.1). In that case strategy one is not to preferred.
The *weight* of the spare part. When the spare part is very heavy, special transport is necessary to transport the part to the NSO. In that case it is impossible for the service engineer to transport the part to the NSO with his own car. When special transport has to be arranged to transfer the part to the NSO, it is to preferred to transfer the part directly to the central stock point; transport costs are saved and the return time will decrease.
Customized or non-customized spare part. In case of a customized repair a short return time is important. A short return time can be realized when the number of entities in the return flow structure decreases.
The *geographical spread* of the customers. A large geographical spread of the customers causes some service engineers to be located far away from the NSO office. When the service engineer is located far away from the NSO, it is preferred to deliver the defective parts without intervention of the NSO at the central stock point of defective parts (strategy two). When the engineer is located nearby the NSO, the engineer visits the NSO almost every day, he has to deliver the defective parts at the NSO (strategy three).
The *value* of the spare part. In case of expensive parts, a short return time from the customer to the central stock point is needed. Long return times cause high interest costs; money invested in pipeline stock and safety stock.

The *moving-rate* of the spare part. The slow moving parts have a high obsolescence risk. Because the high obsolescence risk, the stock of the parts must be as low as possible (given the customer needs). The most economical way to control the stock of the slow-moving parts is to realize a short repair pool leadtime.
The *transport & handling and inventory costs*. From the costs' point of view, the cheapest strategy has to be chosen.

The above mentioned design parameters and combinations of these parameters determine a certain return strategy.

Return strategy choice
In case of *non-customized repairs (about 90% of all the repairable spare parts)* the total logistic costs must be minimized. The logistic costs consist of transport costs, material handling costs and inventory costs. The relative portion of each of the costs in the total logistic costs, is amongst others dependent on the value of the spare parts. Expensive parts have relative high interest costs and relative low transport costs. In case of expensive parts, it is important that the repair pool inventory level is as low as possible. One of the possibilities to realize low inventory levels is to decrease the return times from the field to the central stock point. A short return time decreases the pipeline inventory level and decreases the reorder level at PCS.
A return time reduction is also preferred in case of slow moving parts. For slow moving parts the inventory must be minimized because the high obsolescence risk. Because approximately 90% of the IE repairables are slow moving the number of entities in the return flow must decrease.

In case of *customized repairs* the shortest way to return the defective parts is strategy number one. A prerequisite is that the customer is able to replace the defective part. The choice for return strategy number one is also dependent on the customers' wishes. In general the customers want one Philips 'front door' in their country. From this point of view return strategy one is no good choice, so strategy number two or three has to be chosen.
When the service engineers are located far away from the NSO office, the service engineer has to return the defective parts directly to the central stock point (strategy number two). Return shipments without the intervention of the NSO save transport costs (from the service engineer to the NSO), material handling costs within the NSO and inventory costs due to the stock keeping of defective parts at the NSO for some weeks. When the service engineers are located nearby the NSO office the service engineers have to deliver the defective parts at the NSO office (strategy number three).

The conditions for the return shipments are described in appendix 9.

6.3.2 The collection process

After the description of the return process, now the collection process is described.
In case of central repair in the Repair Centre, there are three possible strategies to collect the defective parts.

Strategies
1. *Collecting at PCS*. The parts coming in from the customers, the service engineers and the NSO's are collected at PCS. PCS is responsible for the distribution of the defective parts to the Repair Centres.

2. *Collecting at the Supply Centre of the OC*. The parts are collected at the Supply Centre of the OC. The Supply Centre is responsible for the distribution of the defective parts to the other Repair Centres.
3. *Collecting at the Repair Centre*. The incoming parts are collected at the Repair Centre. Every NSO, service engineer or customer has to distribute the parts to the Repair Centre.

The best way to organize the collecting process is dependent on the following design parameters.

Design parameters
Customized or non-customized spare part. In case of a customized repair, the repair throughput time can be shortened by approximately 0.5 week (material handling and preparing invoice at PCS) when the defective part is directly shipped to the Repair Centre. In that case strategy number three is preferred (the shortest possible way). In case of non-customized repair, the transport & handling and inventory costs determine which structure has to be chosen.
The *location of the Repair Centre* relative to PCS. When the Repair Centre is situated in the same country as PCS, it is preferred to deliver the defective parts directly at the Repair Centre. Because no difference exists in transport time and transport costs when the defective parts are delivered directly at the Repair Centre instead of delivered at PCS. When the Repair Centre is located in another country the transport & material handling costs determine the collecting structure.
The *location of the NSO's* relative to the Repair Centre. When the NSO is situated nearby the Repair Centre, it is preferred that defective parts are delivered at the Repair Centre without intervention of PCS.
Number of Repair Centres per OC and the number of repairs per annum per Repair Centre. When an OC has one Repair Centre, it is preferred to collect the parts at the Repair Centre (strategy number three). When an OC has more Repair Centres, the organization of the return flow without intervention of PCS (strategy one) or the SC (strategy two) causes some problems. These problems are:

- Every NSO must know which part must be shipped to what Repair Centre.
- Communication problems (language).
- Tracing of the repair status. Who is responsible for tracing: the NSO or the Supply Centre of the OC.
- Problems with paying the return price to the NSO's. In the situation that PCS is a part in the return chain, PCS pays the return price to the NSO. But when the parts are directly returned to the Repair Centre it requires much coordination between the OC and the Repair Centres to organize this invoice process.

Transport & Material Handling and inventory costs (see sub-section 6.1.1).

Collect strategy choice
In case of *non-customized repairs* the logistic costs determine the final logistic structure. Given the above mentioned parameters, the transport & material handling and the inventory costs are decisive.

In case of *customized repairs* a short repair time is required. The defective parts must be collected at the Repair Centre (strategy number three).

Chapter 7 Integral Control System for repairable spare parts

After the determination of the basic structure (chapter 6) the next step is the determination of the planning and control system. A planning and control system defines the way how decisions regarding goods flows and capacities are coordinated, to reach the set targets concerning leadtimes and delivery performance. An integral control considers the mutual tuning between the forecasted customer demand of repairable spare parts, the goods flows and the production and repair capacities.

For the description of the planning and control system, one of the twelve possible logistic structures (see figure 6.1) has to be chosen. Because it is impossible to choose an optimal basic structure for all OC's, because every OC has its own specific characteristics, the basic structure is chosen which is the existent structure for seven OC's: basic structure number eight. For this structure the problems concerning the control are investigated (section 5.3). For structure eight, aspects for improvement of the planning and control system are given in this chapter.

The integral control, regarding goods flows and capacities, is applied on four logistic decision levels (see Bertrand et al.[1]). On what level a certain logistic decision will be taken is dependent on the term a decision is related to. In figure 7.1 four hierarchical control levels are distinguished.

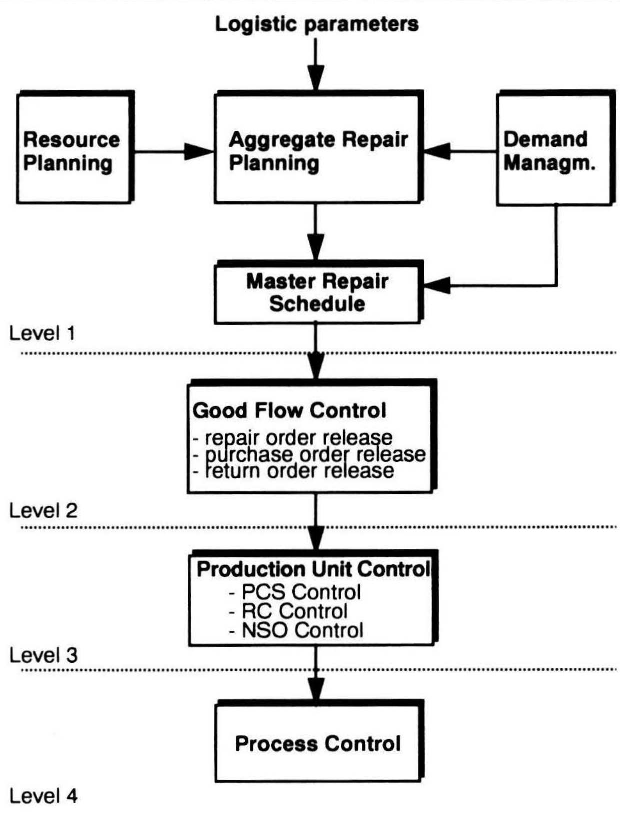


Figure 7.1 Hierarchical control structure

Masterplanning
In this context, decisions must be taken regarding investments in repair and test equipment and investment in service engineer capacity. On the masterplanning level contracts are made between the Repair Centres and the repair department of PCS. The contracts deal with repair leadtimes, repair prices, average batch size, frequency of repair, capacity aspects and the flexibility of the contract. The masterplanning is described in more detail in 7.1.

Goods flow control
The order release decisions are taken on this level. Repair orders are released to the Repair Centres, replenishment orders are released to suppliers, and return orders for the return shipment of defective parts are released to the NSO's. Goods flow control is described in more detail in 7.2.

Production unit control
The prime task of the production unit control is to insure that activities are executed within the agreed time. In the IE logistic control the Repair Centre control (1), the PCS control (2) and the NSO control (3) are distinguished .
1. A repair order through a Repair Centre consists of a number of process steps. The order flows via a number of queues through the Repair Centre. The following typical *Repair Centre control* decisions can be distinguished [1]: repair order detail planning, allocation of available capacity to the repair and test activities and the work and material issuing.
2. The logistic and administrative activities, within *PCS*, concerning the receipt of the return shipments from the NSO's and the despatch of the defective parts to the Repair Centres, have to be executed within the agreed time set by the OC and PCS.
3. The *NSO* has to coordinate the activities concerning the return shipments from the NSO to the central stock point of defective parts, within the agreed time set by the OC.

Process control
The process control consists of the control of the individual repair and test activities in the Repair Centre.

Masterplanning and goods flow control concern to the entire logistic chain of the repairable spare parts; Supply Centre, Repair Centre, PCS, NSO, Field Service Engineer and the Customer. Both control levels are parts of the overall supply chain control, where the masterplanning is focused on the capacity aspects and the goods flow control on the material aspects. Production unit control and Process control concern to one link of the entire chain.

From now on the investigation is focused on the masterplanning (section 7.1) and the goods flow control (section 7.2); attention is only paid to the inventories laying down in the decoupling points and the pipeline inventories. In section 7.3 is described which entities are responsible for the execution of the logistic decisions.
To measure and control the whole repair process, performance indicators are given in section 7.4.

7.1 Masterplanning

The Masterplanning deals with the capacity aspects of the control of the flow of repairable spare parts. Within this control level two sub levels are distinguished. The aggregate repair planning is described in 7.1.1 and the master repair scheduling in 7.1.2. These levels concern the same process, but have different time intervals. Within the aggregate repair plan long term decisions, during the service period, are taken regarding capacity acquisition. The decisions within the master repair schedule concern capacity utilization of the capacity resources at the Repair Centres. The time horizon of the master repair schedule is one year.

7.1.1 Aggregate repair planning

Based on the given service period length and the forecasted repair demand during the service period, the required repair and test capacity is determined. The required capacity is matched with the available capacity, and in case of capacity shortage, investments concerning repair and test equipment, and service engineers are initiated. On this level agreements are made between the service logistic department of the OC, the repair department of PCS and the Repair Centres about the duration of the repair obligation. The Repair Centres have to guarantee the availability of repair capacities and spare parts until the end of the service period.

The process of matching the needed versus the available capacity has three inputs.

Demand management
The primary input for the control of the repairable spare parts is the forecasted repair demand per service code number (P_{tr}, see section 5.2). The forecasted repair demand multiplied with the average repair time (in hours) within the Repair Centre, gives an indication about the expected necessary number of capacity hours per annum. Per Repair Centre the expected number of required capacity hours have to be aggregated for all the service code numbers which are repaired at that Repair Centre.
Within PCS the repair demand is forecasted with information out of the past.

Resource planning
Information about the availability of repair and test resources is matched with the expected required repair and test resources. When the available resources are not enough, capacity has to be acquired to reach the targets concerning leadtimes and delivery performance.

Logistic parameters
The logistic parameters are: the capacity utilization degree within the Repair Centre, the average repair batch sizes, the repair times per service code number, the return leadtimes of defective repairables from the NSO's to PCS, the safety stock at PCS and the delivery performance of new/repaired parts from PCS to the NSO's.
The logistic parameters relate to each other: a high utilization degree and big repair batch sizes will lead to long repair leadtimes and a low delivery performance [1]. When an OC wants a delivery performance of 95% and a lower safety stock level at PCS, the repair times and the return times must decrease. The repair times can decrease when the capacity utilization degree decrease (creation of overcapacity) and when the batch sizes decrease. The return times can decrease when fixed agreements are made between the OC and the NSO's about the return leadtimes.

One of the conditions for an improved control of the flow of repairable spare parts, is that every OC has to set targets concerning the above mentioned parameters. The other conditions are the set-up of an logistic organization (section 7.3) and the use of performance measuring system (section 7.4).

7.1.2 Master repair schedule

At the aggregate repair planning level the capacity acquiring decisions are taken and targets are set concerning the logistic parameters. Given the agreements concerning the logistic parameters, a capacity reservation plan (master repair schedule) between the repair department of PCS and a Repair Centre have to be made. Per time period the repair department has to reserve repair capacity per Repair Centre. The capacity quantity to be reserved is dependent on the forecasted repair per annum, for all the repairables repaired at a certain Repair Centre. This capacity reservation plan must be an absolute agreement between the repair department and the Repair Centre. Agreements have to be made about the frequency of repair and the average repair batch sizes (with a low variation).

7.2 Goods flow control

The goods flow control concerns the goods flow and the inventory levels in the entire chain. On this control level the decisions are taken to realize enough stock of new/repaired parts at PCS, to guarantee a delivery performance of 95%. This means in practice that orders are released to the production units (a release decision gives an explicit destination to material and capacity). The goods flow control structure is depicted in figure 7.2 on next page.
As shown in figure 7.2, the inputs for the goods flow control are the agreements made on the masterplanning level, and the information about the stock levels. Given the agreements about the return, the repair and the purchase leadtimes, and the information about the stocklevels, orders must be released.
The releases of repair orders to the Repair Centres and the releases of purchase orders to the Supply Centres are necessary to control the stock of new/repaired parts at PCS. The inventory control of the repairable spare parts is described in sub-section 7.2.1. Repair orders can only be released when defective spare parts are stocked at PCS. To realize that defective parts are stocked at PCS, the return flow of defective parts from the NSO's to PCS has to be coordinated. In sub-section 7.2.2 the return flow control is given. The customer order acceptance is not further described because it is outside the scope of this investigation.

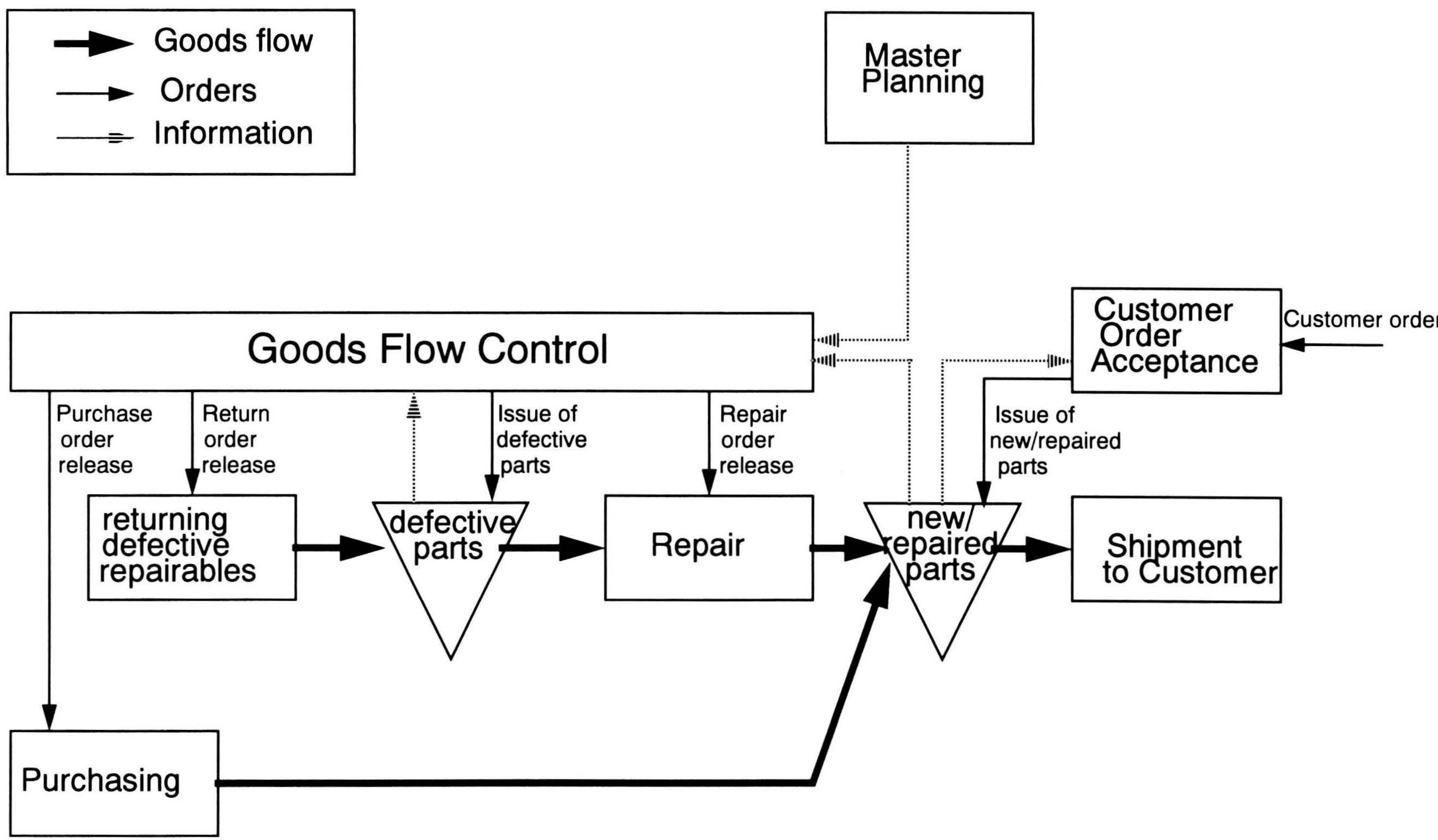


Figure 7.2: Goods flow control

7.2.1 Inventory control of the repairable spare parts

In this sub-section an inventory model for repairable spare parts is described. The reorder levels for repair and purchase are determined to control the inventory of the repairable spare parts. The model description concerns the repairable inventory system described in the following paragraph.

The repairable inventory structure
The repairable inventory structure is depicted in figure 7.3. The inventory of repairables consists of new/repaired and defective parts. The stock of new/repaired parts is supplied from two sources: repair and purchase . The stock of defective parts is waiting for repair at the Repair Centre. In general the defective parts are repaired upon failure, but there is no perfect recoverability. A percentage of the defective parts are not returned from the field and a percentage of the returned parts is irrepairable (see the following paragraph). The positive scrap rate causes new parts to be purchased from time to time to replace those parts which are scrapped. In the cases where no perfect recoverability exists, the purchase and repair function will interact.

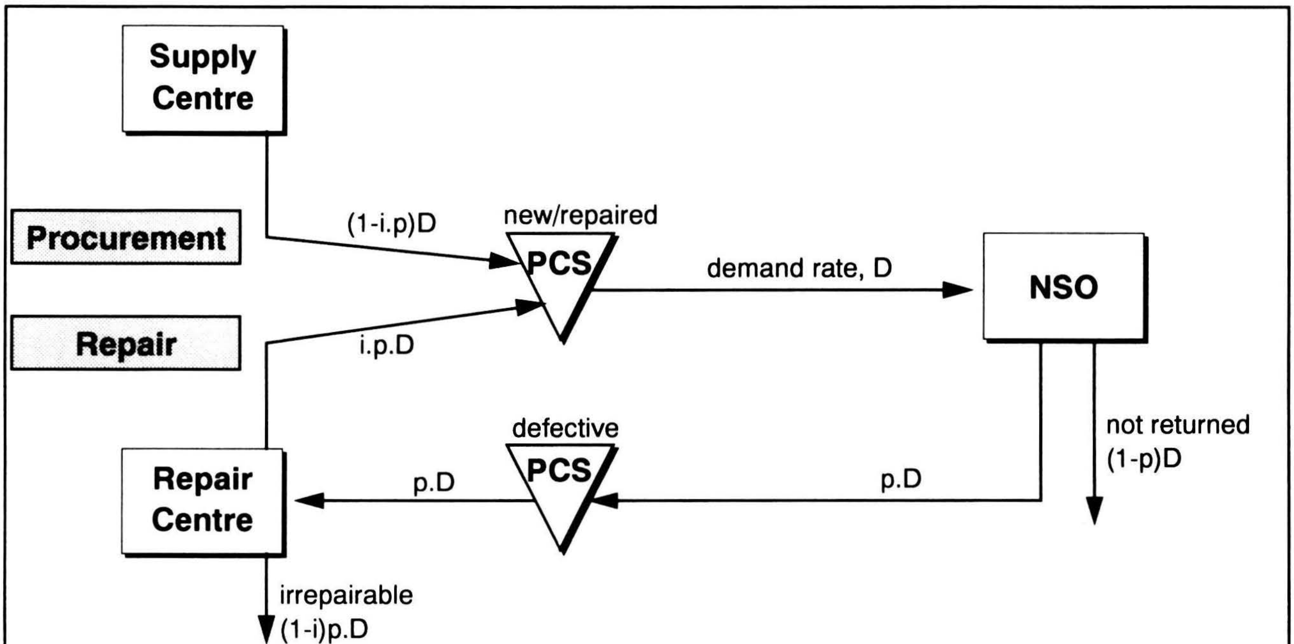


Figure 7.3: Repair inventory structure

Two categories of system losses are distinguished:

- Not every defective part will be returned to the central stock point of defective parts by the field. The return rate (p) is the percentage of defective parts returned from the field.
- Not all returned defective parts can be repaired; some parts turned out to be irrepairable. The repairable rate (i) is the percentage of returned parts that are repairable.

The total scrap rate is (1-ip). These losses are replaced through the purchase of new parts. The recovery rate (r) is equal to ip and measured as a percentage of the demand rate. In the model description only the parameter r is mentioned.

Model description

Schrady [10] formulates a deterministic model for a repairable inventory system. The assumptions behind this deterministic model are mentioned in appendix 11. Some of the assumptions are not valid for the IE situation: the demand of IE repairables is not deterministic and known, the repair capacity is not unlimited and the repair leadtimes are not fixed. But the model description of Schrady is still suitable when safety stocks are kept on stock to cover the uncertainty with respect to the demand during the lead time and the uncertainty with respect to the leadtimes, and when fixed capacity agreements exist (see section 7.1).

The first step is the determination of the repair/purchase policy regarding the replenishment of the stock at PCS. This policy describes in which way the stock of new/repaired parts is replenished and how the repair and purchase activities would interact whit each other. The objective of determining the optimal repair/purchase policy, is to supply as much of the total demand as possible with repaired parts, thus minimizing purchase. The following policies are distinguished:
The 'continuous supplement' policy: When the stock of defective parts reaches a determined level, a repair order will be released (repair trigger). Whit this policy the stock of defective parts will be minimized.
The 'substitution' policy: Defective parts are repaired only when a real demand exists. With this policy the stock of new/repaired parts will be minimized. The background behind this policy is the trade-off between the stock holding costs of new/repaired parts and the stock holding costs of defective parts. The stockholding costs of defective parts are less than the stockholding costs of new/repaired parts. Thus it is preferred to hold inventory in the defective condition. With this policy the stock of new/repaired parts will be minimized. Given this advantage, the substitution policy is preferred above the continuous supplement policy.
The time histories of the new/repaired and defective inventories for the substitution policy are shown in figure 7.4 on next page. As shown in figure 7.4, defective parts will be repaired when the stock of new/repaired parts undershoots the R-level.

Mathematical formulation of the reorder levels

As described in section 5.2, in the inventory control of repairable spare parts two reorder levels are distinguished: the repair reorder level and the purchase reorder level.

- Repair reorder level

When the economic stock of new/repaired parts (section 5.2) undershoots the R-level, a repair order will be released to the Repair Centre. The R-level consists of a buffer part to cover average demand during the average repair times and a safety part to cover the uncertainty in repair times and demand variation during the repair time.

The formula of the R-level is given below.

$$\text{R-level} = \frac{(P_t + P_{tr}) * R_t}{52} + SS$$

R_t : Repair leadtime

$$SS = k * \sqrt{\left(\frac{P_t + P_{tr}}{52}\right)^2 * \sigma_{Rt}^2 + \left(\frac{R_t}{52}\right)^2 * \sigma_D^2}$$

σ_{Rt}^2: variance in the repair leadtime
σ_D^2: variance in the demand

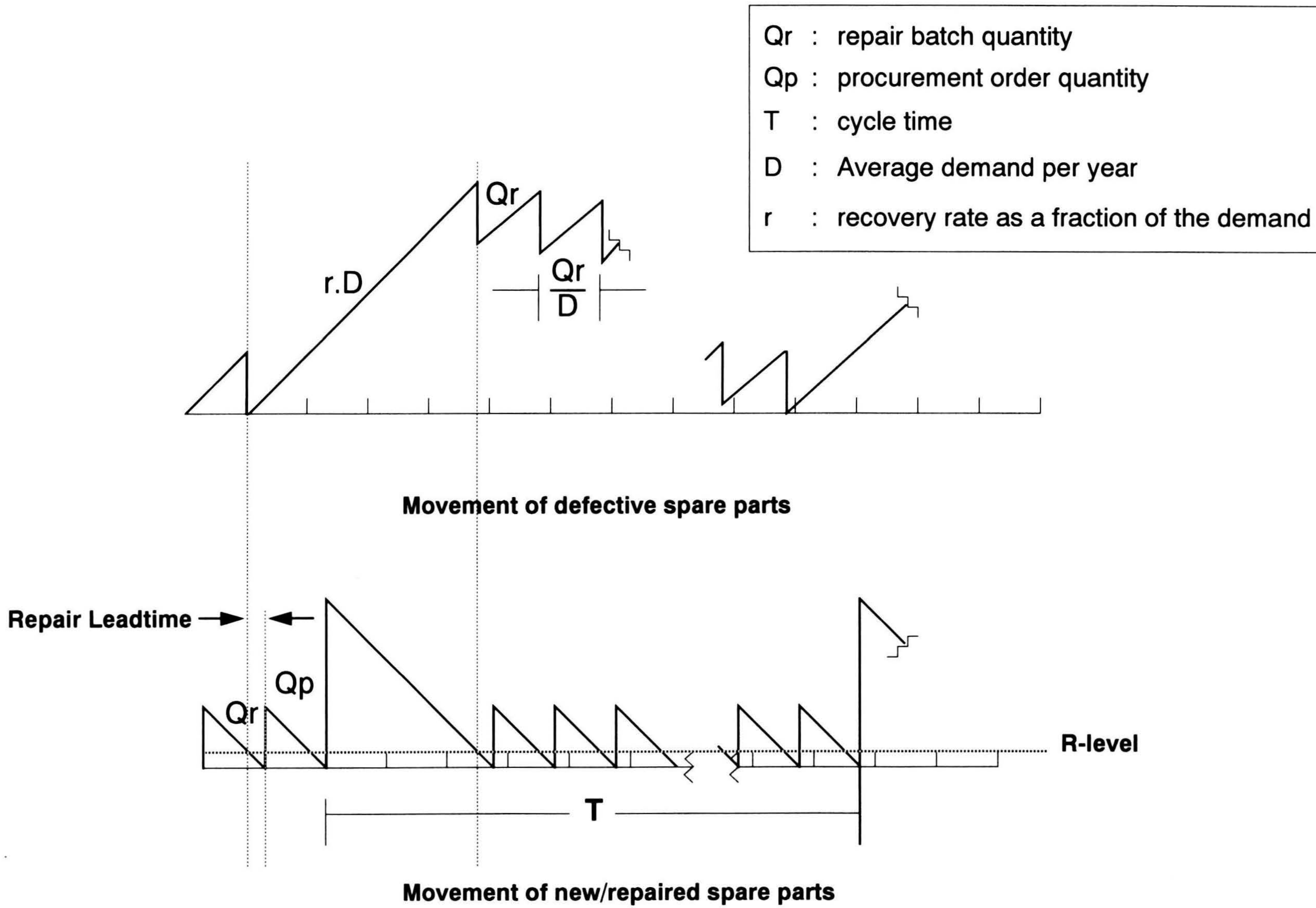


Figure 7.4: Movement of spare parts

- Purchase reorder level

The B-level indicates the number of defective and new/repaired parts in the entire chain, that must be available to guarantee the customer the agreed delivery performance. When the economic stock of defective and new/repaired repairables (see section 5.2) undershoots the B-level, new parts have to be ordered at the Supply Centre.

The determination of the B-level is based on three parameters:

1. the annual demand;
2. the delivery performance with respect to the deliveries of the new/repaired parts to the customers;
3. the repair loop leadtimes (see appendix 10);

The annual demand of repairable spare parts can be forecasted. The total forecast of repairables per annum can be divided in a normal forecast (P_t) and in a repair forecast (P_{tr}). The normal forecast is the forecast regarding the parts ordered without returning the defective parts (no exchange via the repair procedure). The following reasons exist for not returning defective parts: the defective parts are damaged and irrepairable or the customers do not use the repair procedure or there are no defective parts (the customer orders the parts for the safety stock).
The repair forecast regards the parts which are exchanged via the repair procedure.
The definition of the B-level is given below.

$$\text{B-level} = \frac{P_t * L_p}{52} + \frac{P_{tr} * L_r}{52} + SS$$

L_p: Average leadtime of purchasing new parts (weeks)
L_r: Average repair loop leadtime (weeks)
SS: Safety stock

According to this formula the B-level consists of a buffer part to cover average demand during the average leadtimes and a safety part. The size of the safety stock has to depend on the amount of uncertainty. Two types of uncertainty are distinguished: uncertainty with respect to demand during the leadtimes and uncertainty with respect to the leadtimes.

The safety stock formula is:

$$SS = k* \sqrt{\left(\frac{P_{tr}}{52}\right)^2 * \sigma_{Lr}^2 + \left(\frac{L_r}{52}\right)^2 * \sigma_{Dr}^2 + \left(\frac{P_t}{52}\right)^2 * \sigma_{Lp}^2 + \left(\frac{L_p}{52}\right)^2 * \sigma_D^2}$$

σ_{Lr}^2: variance in the repair pool leadtime
σ_{Lp}^2: variance in the leadtime
σ_D^2: variance in the annual demand within the normal forecast
σ_{Dr}^2: variance in the annual demand within the repair forecast
The factor k is used to control the stock out risk.

The mathematical derivation of the order quantities is described in appendix 11.

7.2.2 Return flow control

The defective parts have to be returned from the countries to PCS within the agreed return time. In general there are two ways of organizing the return flow: push control and pull control.

Push control
Every OC has to make appointments with the NSO's about the frequency of return shipments. This appointment has to be a compulsory rule for the NSO. After receiving the defective parts from the engineers and/or the customers, the NSO is responsible to return the parts with a certain frequency. The conditions to realize fast return shipments are:

- Make return procedures for the NSO's.
- Make the officers of the service logistics department aware of the importance of a fast return delivery.
- Measure the return performance of the NSO's.

In the paragraph above, the return flow from the NSO to PCS is described. Now more attention is paid to the return shipments from the service engineers. The engineer is obliged to return the defective items with a certain agreed frequency (e.g. once a week). The 'returned to' address is dependent on the frequency an engineer visits the NSO. Some engineers visit the NSO every day; it is their headquarter. It is preferred that they deliver the defective parts to the NSO. When the engineers visit the NSO less than once a month, it is preferred that they send the defective parts directly to PCS (see sub-section 6.3.1). The conditions to realize fast return shipments are:

- Make field service procedures for the engineers when parts are directly shipped to PCS. For example: After the replacement of the defective part from the system, the engineer has to put the defective part in the box of the new part.
  On the box the 'shipped to' information must be mentioned. This can be realized by putting a sticker, with the "shipped to" information, in the box of the new part. The engineer only has to stick the sticker on the outside of the box. The engineer sends the box(es) every day to PCS.
- Make the engineers aware of the importance of a fast return delivery.
- Measure the return performance of the service engineers.

Pull control
PCS releases a return order to the NSO's when defective parts are needed for repair. On the return order, the parts are mentioned that have to be returned within an agreed time frame. This way of organizing makes it possible for NSO's to batch defective parts until the moment a return order is released. So transport costs may decrease.

The best way to organize the return process is a combination of push and pull control. The NSO's are responsible for returning the parts within the agreed time. When the NSO's do not perform on the right way, PCS has to send a return order to the NSO's.

7.3 Logistic organization

In section 7.1 and 7.2 the planning and control system is described. A lot of decisions are defined to coordinate the activities concerning the flow of the repairable spare parts. The defined decisions have to be executed. To ensure that tasks are executed, for each task one entity is responsible.
The service department of the OC has the total responsibility about the whole spare parts supply chain. They are also responsible for the return process of the repairables. Some parts of the responsibility are delegated to other entities. The responsibilities concerning the return flow of the repairables, are mentioned table 7.1.

Table 7.1: Responsibilities distribution

Responsible entity	Responsible for
OC service department	- to set targets for the NSO's concerning the return frequency - make appointments with PCS and the Repair Centre about the service period length, repair times, capacity utilisation degree, and repair prices
Service engineer	- return defective parts within the agreed time
NSO	- return defective parts within the agreed time - measure and control the return process from the service engineer to the NSO
PCS	- make a master repair schedule for each Repair Centre - stock control of new/repaired and defective spare parts release of the repair orders release of the purchase orders release of the return orders - make demand forecasts - measure and control of the flow of the defective parts still to be received from the NSO's - measure and control of the outstanding repairs at the Repair Centres
Repair Centres	- repair within the agreed time

7.4 Performance measuring

The performance of the return and repair activities must be measured to ascertain the extent to which kind and nature the current repair services meet actual market requirements. Every NSO has to investigate the customer requirements concerning repairs. These requirements must be linked to performance parameters. These parameters have to be measured by performance indicators as depicted in figure 7.5. A performance indicator is defined as a variable, indicating the effectiveness or efficiency of a part or the whole of the process or system against a given norm, target or plan. With the help of performance indicators it is possible to express the performance of the flow of defective repairables, regarding logistic (time, place, quantity), quality and costs aspects.

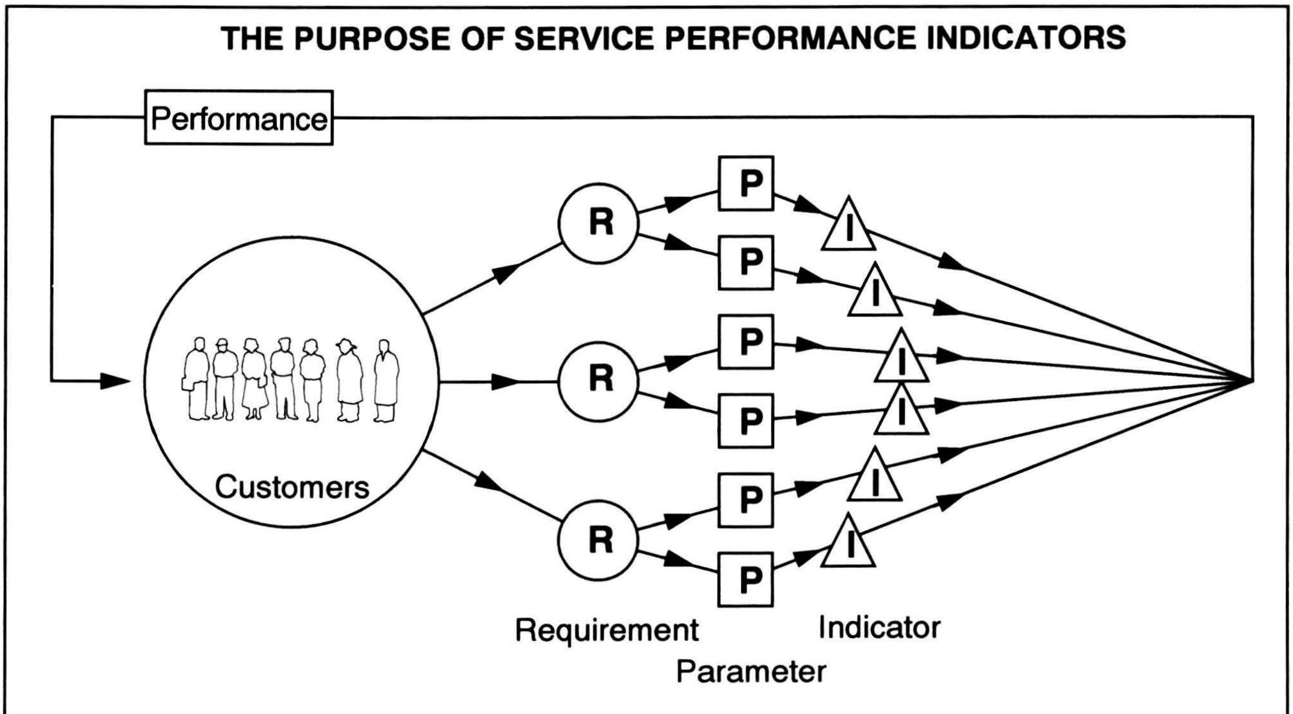


Figure 7.5: Performance Measuring

In this investigation the performance measuring is restricted to the logistic (time, place and quantity) and the cost aspects, concerning the return flow of the repairables. The realized performance, measured with the performance indicators, has to be related to the defined targets. When set targets are not realized, decisions must be taken to improve the current situation. An improvement of the current situation can result in a change of the organization, the control structure or even the basic structure.

For every product market combination of every OC, the service logistic department of the OC has to set norms and targets for the performance indicators.

External and internal performance indicators are distinguished. The external indicators express the performance of the repair service delivered by the entire IE Philips organization to the end users, see sub-section 7.4.1. The internal indicators express the performance of the internal IE Philips process, see sub-section 7.4.2.

7.4.1 External indicators

Every NSO has to measure the repair service performance delivered to the end users. The market requirements concerning central repairs are linked to parameters. In service contracts one of the following parameters is specified

- Repair time in case of on site repair executed by the service engineer; time between starting repair and finishing repair.
- Down time in case of on site repair executed by the service engineer; time between the call entrance at the call despatch department and the finishing of the repair.
- Turnaround time for central repair; time between the despatch at the customer (the customer ships the defective part to the NSO office or the service engineer takes the defective part back) and the receipt at the customer.

All these parameters are measured in hours or days.
These parameters determine the way a NSO has to handle the non-customized and the customized repairs.
In case of non-customized repairs the following performance parameters are important:

- Availability of new/repaired parts at PCS: the number of failures to meet customers' requests in relation to the total number of requests.
- On time delivery: the number of on time deliveries (given the delivery time) in relation to the total number of deliveries.
- Correct delivery; the number of correct deliveries in relation to the total number of deliveries.

In case of customized repairs a turnaround time has to be realized so that customer requirements are met. The following parameter must also be measured to determine the performance of the customized repairs:

- On time delivery: the number of on time deliveries (given the with the customer agreed repair time) in relation to the total number of deliveries.

7.4.2 Internal indicators

The performance of a part or the whole of the return process must be measured to ascertain the extent to which the internal targets, concerning the return flows, are realised. Two levels of performance indicators are distinguished within the defined basic structure:

1. Performance of each entity in the contribution chain. The object of performance measuring is the output of one entity of the entire chain (the entity is seen as a black-box).
2. Performance per department of a certain entity. Within one entity a number of departments are concerned with the return process. The performance of every department must be measured.

The two levels of performance measuring concerning the internal indicators (and the external indicator level) are illustrated in figure 7.6.

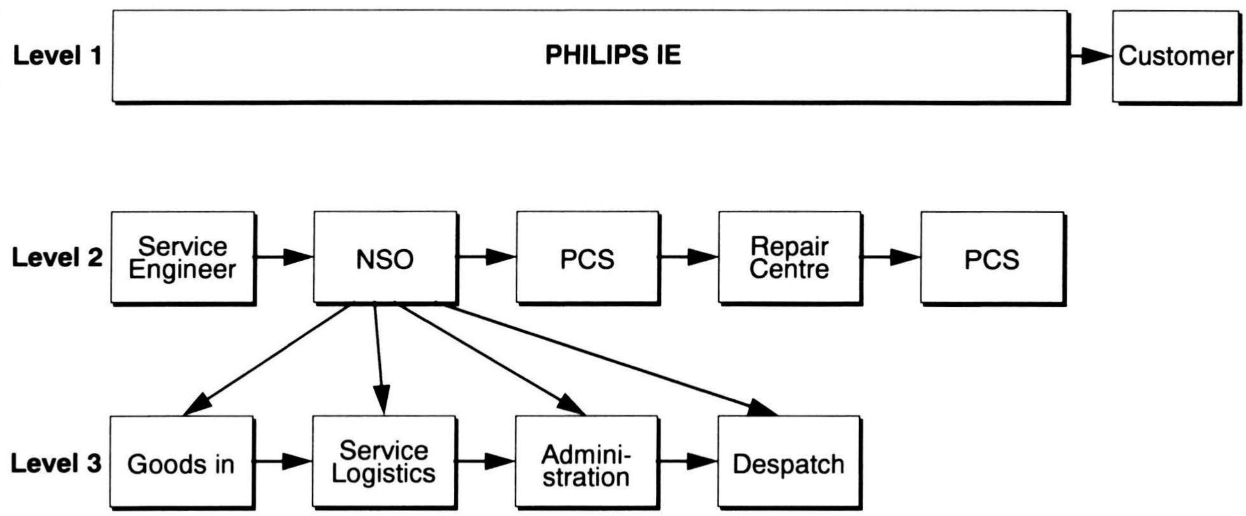


Figure 7.6: Three levels of performance measuring

While only the goods movements on the goods flow control level are considered in this investigation, performance indicators on the department level are not taken in further account. The performance parameters and performance indicators dealing with the first and second level are mentioned in appendix 12.

Chapter 8 Control of the repairable spare parts at the OC Electron Optics

The theoretical description of the determination of the basic structure (sse chapter 6) is practised for one product market combination of the OC Electron Optics. EO provides electron microscopes for the professional markets.
Before the determination of the basic structure, for the chosen product market combination, is given in section 8.2, first some general aspects regarding the flow of EO repairables are mentioned in section 8.1.

8.1 General aspects

EO has delegated a part of the service logistics of their service operation to PCS. The total number of service code numbers stocked at PCS is 3579. The number of service code numbers participated in the PCS repair procedure amounts to 222. Information concerning moving rate, repari code, repair address, repair leadtimes and repair forecasts is shown in appendix 13. A multiple criteria analysis is executed for the EO repairables. The in appendix 13 described analysis gives a classification of the 222 repairable spare parts in categories based on the Dfl.-usage value (value times the annual usage). With the help of this analysis the product with the biggest Dfl.-usage value is chosen for further investigation (see 8.2).
Some aspects concerning the flow of EO repairables are mentioned in appendix 14. The mentioned topics are, the arrival frequency of defective repairables at the NSO, the through put time within the NSO, the arrival frequency of defective repairables at PCS and the repair order release frequency from PCS to the Repair Centres. The delivery performance of the Repair Centres to PCS is about 56%, see appendix 15.

The total number of forecasted repairs is approximately 420 per annum. This means that 420 defective repairs are shipped from the NSO's to PCS and PCS distributes the defective parts to the Repair Centres. The forecasted annual PCS costs are approximately Dfl 230,000.=. The forecasted annual PCS costs are calculated by multiplying the forecasted repair (P_{tr}) with the difference between the customer repair price (CREPRS) and the repair price (REPPRS), for each part. The customer return price is the price a NSO has to pay for repair and the repair price is equal to the price PCS has to pay to the Repair Centre.

About 70% of the forecasted repairs have to be distributed to the Repair Centre of EO in Acht, 20% to Power Systems in Wavre, 5% to Philips Almelo and the remaining to the other eight Repair Centres. In the future the power supplies will be introduced in the Power Supplies direct repair procedure (see appendix 4). So the defective power supplies will not be sent to PCS any more.
When the Power Systems repairs are not taken into account, about 90% of the EO repairables which arrived at PCS are forwarded to the Repair Centre of EO in Acht. Because PCS adds no value for EO (no repair or test activities are executed), it is recommended to ship all defective parts directly from the countries to the Repair Centre of EO. Costs saving and leadtimes shortening is possible. Further investigation concerning the organizational aspects is necessary.
Especially concerning the customized repairs of EO, the repair leadtime in case of central repair, with intervention of PCS, is too long (customers are unsatisfied about the repair leadtimes) and too much logistic incidents occur (customers do not get their own repairable back). The first action to shorten the repair time is to deliver the defective parts from the NSO's to the Repair Centre, without intervention of PCS.

8.2 The control of the goods flow of a HT generator

The product with the highest annual Dfl.-usage value, the HT generator (code number 5322 218 40041) is chosen for further investigation. The characteristics are described in 8.2.1 and the basic structure in 8.2.2. In 8.2.3 the results of leadtime reduction are given to show the impact of a leadtime reduction on the total integral logistic costs.

8.2.1 Characteristics

Quantitative information concerning the market, product and process characteristics are given to calculate the logistic costs given a certain basic structure.

Market characteristics

- New/repaired parts must be delivered within five days with a delivery performance of 95%.
- The forecasted repair demand (P_{tr}), for the coming year, is 8 pieces and the normal forecasted demand (P_t), for the coming year, is 1 piece.

Product characteristics

- The weight of the HT generator is 200 kg (weight information is needed to calculate the transport costs).
- The spare part has repair indicator 1; this article can either be obtained as a new part or exchanged via the repair procedure (also called the exchange procedure) and the part is thus a non-customized part.
- Price information is given to calculate the costs.
  Standard Stock Price (SSP), the stock price at PCS: Dfl. 19,830.=
  Key Price, the price a NSO has to pay for a new/repaired part: Dfl. 43,100.=
  Customer Repair Price (CREPRS): Dfl. 8,380.=
  Repair Price (REPPRS): Dfl. 5,680.=

Process characteristics

Some information about leadtimes is given.

- The return time from the NSO to PCS (rpktime) = 8 weeks.
- The internal PCS time is approximately one week.
- The repair leadtime at Philips Almelo (reptime) is 18 weeks.
- The test leadtime at EO in Acht is approximately one week.
- The delivery time (deltime) in case of replenishment orders of new parts is 37 weeks.

8.2.2 The basic structure

The repair capacity structure and the inventory structure of the defective parts is determined.

Repair capacity structure

Referring to section 6.1 the repair capacity structure is described. Philips Almelo (Manufacturing WAA) is the supplier and the repairer of the HT generators. All specific repair equipment is located only at Philips Almelo. After the repair, the HT generators have to be functional tested in the Repair Centre of EO in Acht because the repair quality can only be guaranteed when the HT generator is tested. From the quality point of view the HT generator has to be repaired centrally.

Because the HT generator is a non-customized part, the repair time is not important for the customer, the integral costs are decisive by choosing the repair structure (see 6.1.2). Given the low forecasted repair demand for the coming year (P_{tr} = 8), it is from the costs' point of view preferred to repair centrally. In case of local repair the investment costs in equipment and training are much too high because very expensive microscopes are needed for testing. Because the investment costs are very high and the transport costs are low (related to the investment costs) the part has to be repaired centrally.

Inventory structure of defective repairables
The return process from the country to the central stock point and the central collecting process is determined.

- The return process

EO wants no return flow of defective parts without intervention of the NSO or a service engineer. This means that strategy number two (service engineer return the parts to the central stockpoint) or strategy number three (NSO returns the parts to the central stockpoint) has to be chosen (see sub-section 6.3.1).
In the existent situation the defective HT generator is transported from the customer to the NSO, and the NSO transports the part to PCS. To transfer the defective part to the NSO special transport has to be arranged, because the service engineer is not able to transport the part to the NSO (the HT generator is very heavy).
The geographical spread of the customers has no influence on the return strategy choice because the service engineer is not able to transfer the HT generator.
The value of the part is very high so short return times are preferred to keep the inventory costs as low as possible.
From the costs' point of view it is cheaper to transport the defective part directly to the central stock point (return strategy number two). The transport costs from the customer to the NSO are saved and the inventory costs will decrease because the total return time will decrease. One of the conditions to realize this return flow is that the service engineer prepares the shipping documents.

- The collection process

Concerning the collection process three strategies are possible (see section 6.3.2). In case of the HT generator the strategies are depicted in figure 8.1 on next page. Because the actual situation is that the NSO sends the defective part to the central stock point, the NSO is in figure 8.1 chosen as the entity which sends the parts to the central stock point. Because the Repair Centre is located in the same country as PCS, from the costs and time's point of view it is recommended to deliver the defective parts directly to the Repair Centre (strategy number three).

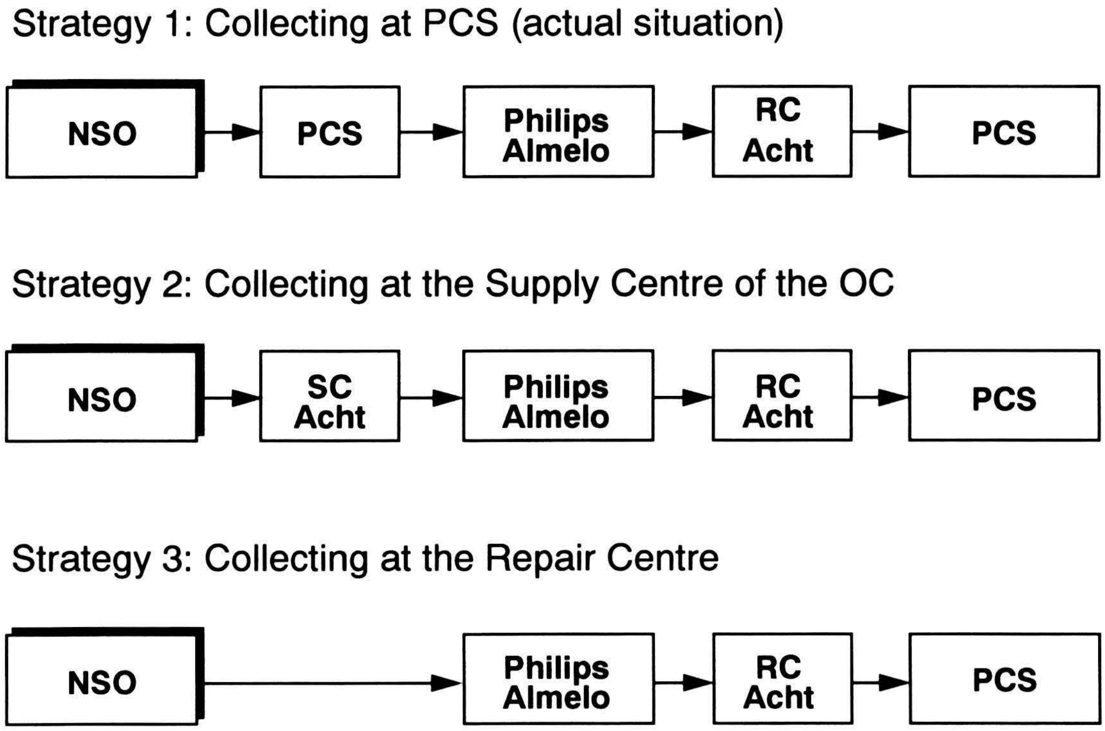


Figure 8.1: The three possible collection strategies

For all strategies the logistic costs are determined.

Logistic costs per basic structure
With the help of the information from section 8.2.1, the total logistic costs per annum, concerning the collection process, are calculated. The following logistic costs are distinguished.

- Inventory Costs

The interest costs and stocking costs are related to the money invested in the stock of the pieces in the repair pool.
The repair pool level consists of all defective and new/repaired parts in the entire chain.
The repair pool level is calculated with the formula of the B-level (see section 7.2)
The repair pool level for the HT generator is 5 + 1 (safety stock) is 6. The safety stock is calculated with the at PCS used formula, because not enough information exists about the variation in leadtimes and in the demand.
The interest costs are 15% of the Standard Stock Price and the stocking costs are 3% of the Standard Stock Price.
The total inventory costs per annum are Dfl. 21,416.=

- Transport Costs

For this example the NSO France is chosen. The assumption is done that all defective parts are send from France. Of course this is no reality, but the assumption is made in relation with the transport costs.

The transport costs of the return shipment from France to the Netherlands are Dfl. 385.= per piece per shipment (transport with TNT, 4 days transport).
The total transport costs per annum are Dfl. 3080= (8 * Dfl. 385.=)
The transport costs within the Netherlands are Dfl. 50.= per piece per shipment (Transport with Phil express, 1 day transport).
The total transport costs per annum are Dfl. 400.= (8 * Dfl. 50.=)

- Handling costs

The PCS handling costs are equal to (CREPRS-REPPRS) = Dfl. 2700.= per piece. The total PCS handling costs per annum are Dfl. 21.600,=
The handling costs at Supply Centre Acht consist of physical and administrative handling costs. The physical handling activities, by the Service Logistic Department are the receipt and the despatch of the HT generator, with an average duration of one hour per piece. The administrative handling activities, by the Purchasing department, are the creation of a repair order; with an average duration of 0.25 hour per piece. Given a hour rate of Dfl. 100.= , the handling costs are Dfl. 125.= per piece.
The total handling costs at the Supply Centre per annum are Dfl. 1000.=

The total costs, concerning the collection process, per annum (so for eight pieces) per collection strategy are shown in table 8.1.

Table 8.1: Logistic costs (in Dfl.) concerning the collection process.

Logistic costs	NSO-PCS-Almelo (Strategy 1)	NSO-Acht-Almelo (Strategy 2)	NSO-Almelo (Strategy 3)
1. Interest costs	21416	21416	21416
2. Transport costs			
* France-Neth.	3080	3080	3080
* Acht-Almelo		400	
* PCS-Almelo	400		
3. Handling costs			
* PCS	21600		
* Acht		1000	
Total costs	46496	25896	24496

Conclusion: When the parts are directly delivered from the NSO's to Philips Almelo, the annual integral costs can decrease with approximately 45%.

For the basic structure with the lowest logistic costs, NSO-Almelo, the goods, information and the invoice flow are shown in Appendix 16. The logistic organization is also described in Appendix 16.

8.2.3 Logistic costs in case of leadtime reduction

For the basic structure NSO-Almelo the logistic costs are calculated when repair time and rpktime decrease. This is done to show the impact of leadtime reduction on the decrease of the logistic costs.

- The existent repair time is 18 weeks. At the moment EO and Philips Almelo are discussing about a leadtime reduction. The target is to realize a leadtime of 10 weeks, see table 8.2.

Table 8.2: Repair leadtime

Activity	Time
Repair at Philips Almelo	8 weeks
Transport to EO in Acht	3 days
Test at the repair shop in Acht	1 week
Transport to PCS	2 days
Total	10 weeks

- The rpktime is 8 weeks. When the NSO's ship the defect HT generators direct to Almelo the rpktime can decrease by 6 weeks. So the possible rpktime is 2 weeks. A condition for a fast return shipment is a good agreement concerning the return times, between the NSO's and the service department of the OC.

If the repair time reduction and the rpktime reduction can be realized, the repairpool level can decrease with 2 parts.

The total logistic costs are now Dfl. 14,278.= (inventory costs) and Dfl. 3080.= (transport costs) = Dfl. 17,358.= (total). Another advantage is the repair pool level can decrease with two parts with the result, less money is invested in stock.

Conclusion: A leadtime reduction of the return leadtime and the repair leadtime will result in a decreasing of the total integral logistic costs with approximately 60% (compared with the existent situation).

Chapter 9 Conclusions and recommendations

The conclusions and recommendations exist of general statements, for whole IE, and of Electron Optics specific statements. Also recommendations for further investigation are given.

General

The control of the flow of repairables is unstructured at the moment. In the existent control method the following aspects are not (or not good) defined:

- there are no clear objectives and targets;
- no agreements exists about return times from the NSO's to PCS;
- there is not enough notice (within the NSO's) about the importance of a fast return shipment from the NSO's to PCS (lack of awareness);
- no contracts exists between PCS and the Repair Centres about capacity and time aspects;
- no clear responsibility distribution exists (lack of logistic organization) and;
- no performance measuring system exists.

To improve the existent situation, the following actions have to be executed.

1. Effective management of the spares and repairs logistics processes is vital to the overall performance of the OC's of IE. The OC's need to give maximum customer satisfaction service to the installed base, at minimum costs. This means that every OC service manager has to define logistic, service logistic and repair logistic targets. (For example the PD Medical Systems has defined the following logistic objective: To sustain 'complete and on-time' customer service at > 98% while maintaining a total average gross inventory position of < 25% of total sales).
2. After defining objectives and setting targets, every OC has to determine the optimal basic structure, given customer requirements and integral logistic costs, so that set targets can be reached.
3. The existing planning and control concept has to be improved. The following points have to be met:
   - To decrease the leadtimes and the leadtime variability in the entire repair pool, it is necessary that agreements are made between the OC service department and the NSO's about return times. The performance of every NSO has to be measured with performance indicators.
   - The OC service department has to made agreements with the Repair Centres about availability of repair and test capacity during the service period, repair prices and repair leadtimes. The discussions about the availability of repair capacity and spare parts during the service period, have to be integrated with the discussions between the purchasing department of the OC's and the sales department of the supplier; service needs have to be combined with the commercial needs.
   - The repair department of PCS has to make contracts, master repair schedules, with the Repair Centres about capacity reservation, repair frequency and average repair batch sizes.
     Within the integral control concept, the inventory control system at PCS has to be adapted.
   - The existent repair level is too high and not repair time related. The time related formula, given in sub-section 7.2.1, has to be used.
   - The existent safety stock is independent of the uncertainty in the repair demand during the repair time and independent of the variation in the repair leadtime. So a new safety stock formula is determined (see 7.2.1).

A prerequisite for a good use of this formula is a determination of the distribution function of the demand per IFG. When the distribution function is known, the variation of the demand can be estimated. It is also necessary to measure the repair leadtimes and the deviation.

4. A prerequisite for a fast and reliable flow of repairables is a well defined logistic organization. The service department of the OC is responsible for the entire repair flow; within the service department one person has to be the 'process owner'. When tasks are delegated to other entities, for example PCS, the person remains responsible.
5. After the determination of the optimal basic structure, the planning and control concept and the logistic organization, the performance of the activities concerning the return flow has to be measured to ascertain the extent to which customer requirements and internal goals are reached (important topic in the TQM project). When set targets are not realized, decisions must be taken to improve the current situation. An improvement of the current situation can result in a change of the organization, the control structure or even the basic structure.

The determination of the information needs and the determination of the information systems are not elaborated in this report. Both aspects are very important to realize performance improvement, because the right information is needed to support the logistic decisions. So further investigation is necessary on both aspect.

To set a process of improvement in motion, the service department of the OC has to initiate this process. The above mentioned five actions have to be executed and the aspects information needs and information systems have to be further investigated.

It is recommended to charge all the goods movements. At the moment only the goods movement from the NSO's to PCS is charged. To realize a better repair performance, the charging of the goods movements from PCS to the Repair Centres is an important condition.

EO specific

In future, about 90% of all the defective EO repairables arrived at PCS, have to be transferred to the Repair Centre in Acht. Because the added value of PCS in the return flow is low (no repair or test activities are done), it is recommended to deliver the defective parts directly from the countries to the Repair Centre. Costs will be saved and the total repair loop leadtime will decrease.

At the moment the defective HT generator is delivered from the NSO's to PCS and PCS distributes the defective part to Philips Almelo. When the parts are directly delivered from the NSO's to Philips Almelo, the total integral logistic costs can decrease with approximately 45%.

A leadtime reduction of the return time and the repair time will result in a decreasing of the total integral logistic costs with approximately 60%. Another advantage of leadtime reduction is the decreasing of the repair pool level, so less money is invested in stock and the obsolescence risk decreases.

Recommendation for further investigation

Because the demand pattern for the IE spare parts is irregular and unpredictable (the moment an installation fails is unknown), flexibility is needed to cover the uncertainty in the demand. One sort of flexibility is stock. But given the high percentage of slow moving parts (high obsolescence risk) it is a very expensive sort of flexibility. Short and reliable leadtimes are another sort of flexibility. It is recommended to start an investigation for repair and purchase leadtime reduction, to see of there are possibilities to realize this.

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Appendix 1: IE goods flows

The analysing of the existing IE goods flow is a condition for the improvement of the logistic performance of IE. The analysis contains information about the directions of the goods flows (especially the return flow of the spare parts) of IE products, systems and projects. An overview of all the IE goods flows is given in section 1. The entities involved by the goods flows, are described in section 2. The return flows are described in section 3 and the return flow of the spare parts is described in section 4.

1 Goods flows of IE products

The total physical flow of IE products can roughly be divided in:
- a main flow of finished products, systems and projects to the customers;
- a flow of spare parts to the customers;
- a return flow of finished products, systems, projects, spare parts and (maybe in the future) packing material, starting at the customers' site;
- a flow of finished products and spare parts for disposal to the finishing industries.

The flows of the finished products and the spares are depicted in figure A1.1.

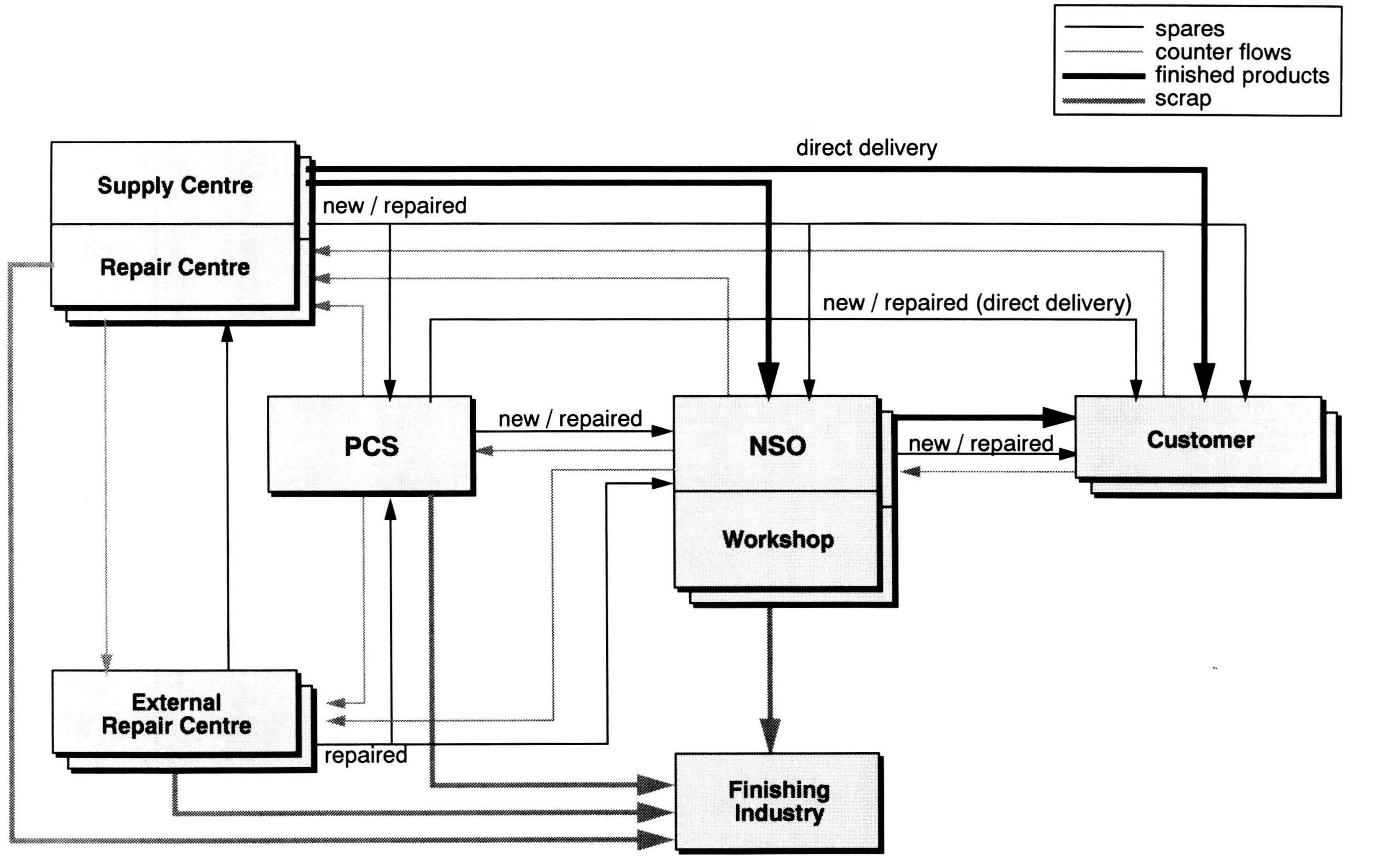


Figure A1.1 Goods flow

Philips Industrial Electronics

J. Graveland 1993

2 Description of the entities in the goods flow

Supply Centre (Supply Centre)
Every Operating Company has one or more Supply Centre's. In the Supply Centre's the OC-specific finished products, systems, projects and spares are manufactured. During the production period, also repairables can be repaired or tested in the Supply Centre. A Supply Centre has a Repair Centre where after the end of production, the repairables can be repaired and tested.

Repair Centres (Repair Centre)
There are internal (situated within a Supply Centre) and external repair centres. In the Repair Centre's the specific technology and know how is available to repair and/or modify repairables and to dismantle apparatus for recycling of valuable and/or future needed modules and components.

Philips Consumer Service (PCS)
PCS is a Business Group of the Product Division Consumer Electronics (CE), amongst others responsible for the CE service policy (central warehousing and distribution of spare parts) world wide. PCS also works for the Product Divisions Industrial Electronics and Communication Systems and for some third parties (=not Philips), who outsource a part of the logistics of their service operation to PCS. The Logistic Operation of PCS is responsible for purchase of spare parts, distribution of spare parts worldwide, stock control of good and defective spare parts and PCS has a repair procedure.

For the IE spare parts, the OC's are financially responsible for the stock control of good and defective spare parts.

National Sales & Service Organization (NSO)
A National Organization consists of a few NSO's. An NSO sells products and supply customer support service for one Product Division. Every NSO has its own sales- and service organization. The service organization supplies services to the customers:
- orderdesk
- inventory control of fast-moving items
- deliver spare parts to engineers and customers
- collect defective spare parts and ship the parts to PCS or to the Repair Centre.
- local repair in workshops
- function as an intermediate between customers/engineers and PCS/Supply Centres
- handling service contracts
- field service repair and maintenance

NSO local workshop
Some apparatus can be repaired in the NSO workshop. For the repair of modules, manufactured with advanced technologies in the Supply Centre's, the modules have to be shipped to the Repair Centre's because the necessary tools and test equipment for repair and test are not available in the workshop.

Regional workshop
The total European market is divided in a number of regions. A region consists of a few countries. Every region has its own regional work shop. The regional work shop gives service support for a few countries around them. These countries are still the "front door" for the customers in receiving defective equipment and returning it after repair. As a result, local repair (in the workshop of the NSO) is no longer necessary.

Field engineer
Field engineers support the customers with amongst others the following services: cleaning of the installations, adjusting of the software, small repairs and the replacement of field exchangeable parts, preventive maintenance and system upgrading.

Customer
The end user of the industrial systems.

Finishing industry
Dealing with the recycling, reusing and central disposal of products.

3 Return flows

In the return flow the following sub-flows can be distinguished:

Finished products
The following reasons exist to return finished products to the Supply Centres:
* wrong deliveries; the wrong- or too much products are delivered.
* the delivered products are damaged during transport.
* the delivered products are defect on arrival at the customer.
* the finished products have to be returned for repair, modification or research.
* at the end of use, the finished products have to be sent back for recycling, reusing or central disposal; in the future the vendor will be responsible for the recycling, reusing or disposal.

Spare parts
The reasons for returning spare parts to the Supply Centre's or PCS are the same as mentioned at the sub flow of the finished products. In section 4 the return flow of spare parts is described.

Packaging
Due to expected environmental legislation, the vendor will be responsible for taking back of the packaging material.

4 Return flow of spare parts

The return flow of spare parts can roughly be divided in two sub-flows:

1. A flow of defective parts for repair or modification
2. A flow of returns

The return flow of spare parts is depicted in figure A1.2.
The flow of repairables is described in detail in chapter 5. In this appendix only the flow of returns is described.

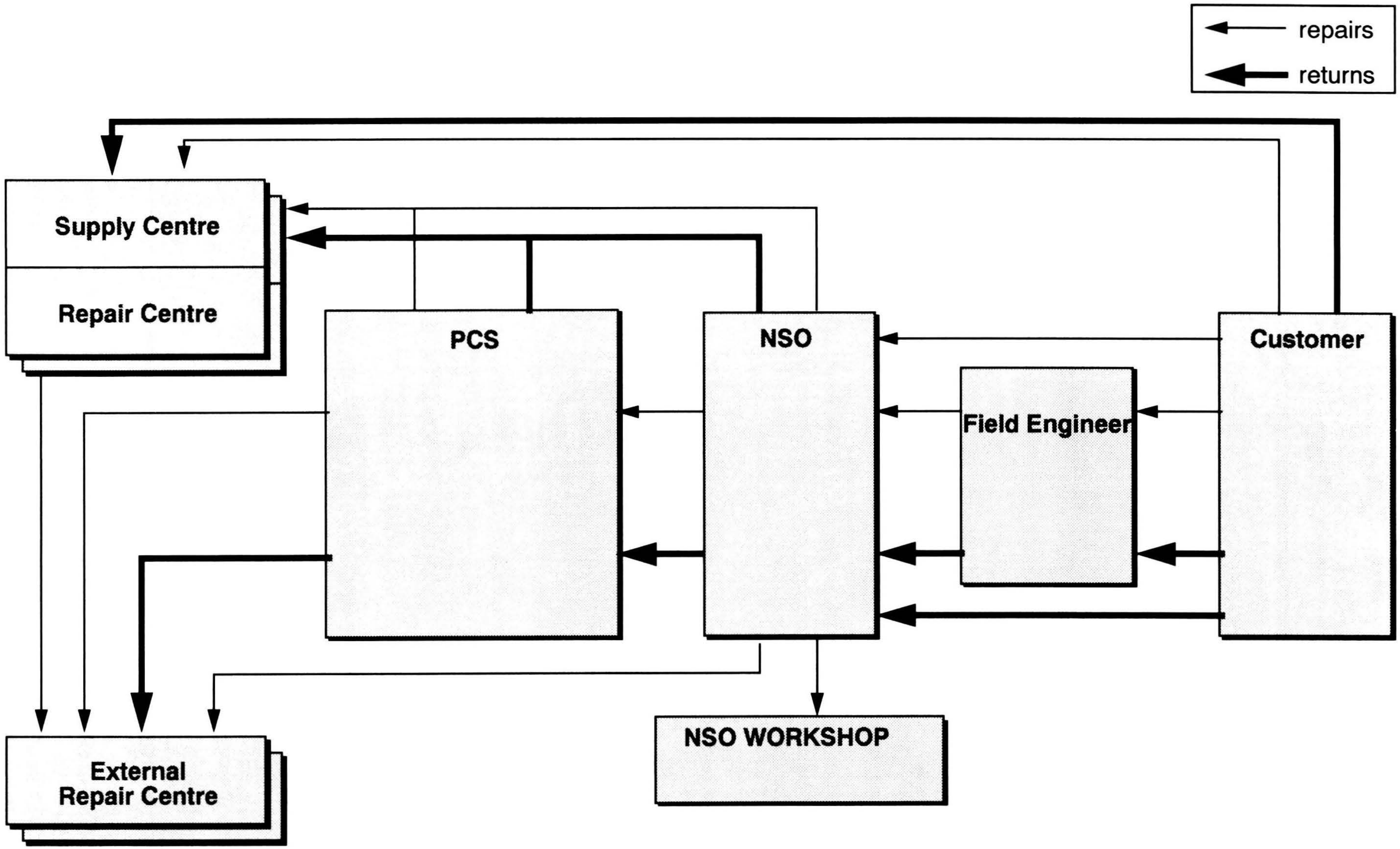


Figure A1.2 Counter flows of spare parts

Ad 2 Flow of returns

The NSO wants to return spare parts if they can be characterized as:

Serviceables
These parts are new, not used. The engineer ordered them with the intention to maintain an apparatus. However, it turns out later that a share of the parts ordered has not been necessary.

Wrong deliveries
The wrong spare parts or the wrong amount of spare parts are delivered at the customers site. These failures have nothing to deal with ordering failures of the customer.

Dead on arrival
Some new parts turn out to be faulty on receipt and therefore cannot be used to repair the apparatus.

Defective repairables not authorized in the repair procedure.
The NSO's want to return these defective parts without ordering a new one. No repair number is requested at PCS.

Recycling / Central disposal
Instruments which contain valuable elements will be collected more and more for recycling. The parts which are containing dangerous elements for the environment, should be collected for central disposal.

Appendix 2: Flow charts of the activities concerning the flow of repairables

The total flow of defect repairables can be visualized by flow diagrams. The flow diagram of the integral chain is depicted in figure 5.2. The relations between the different entities will be analysed in this appendix.

Relation Customer - Engineer
The customer always contacts the NSO first when an apparatus is defective.

Relation Customer - NSO orderdesk
When a failure exists on an apparatus, the customer calls the NSO orderdesk, see figure 1. There are three situations possible:

1. The customer does not know which module/component is defective. In consultation with the NSO is decided that the customer sends the apparatus back to the NSO, see figure 1a.

2. The customer asks for a field engineer . When the defect apparatus is a big system or built in a system it is not advisable to send the system back to the NSO. It is also possible that the customer has contracted the NSO for the repair at the customer site, within a certain agreed time (e.g. within 4 hours), see figure 1b.

3. The customer knows which module/component is defect and has the knowledge to exchange the defect module/component. The customer asks for a spare part at the NSO, see figure 1c.

Relation Customer - Regional Repair Centre
In the case of the OC Power Systems in Wavre, customers can return the defective power supplies to Wavre, without the intervention of the NSO's.

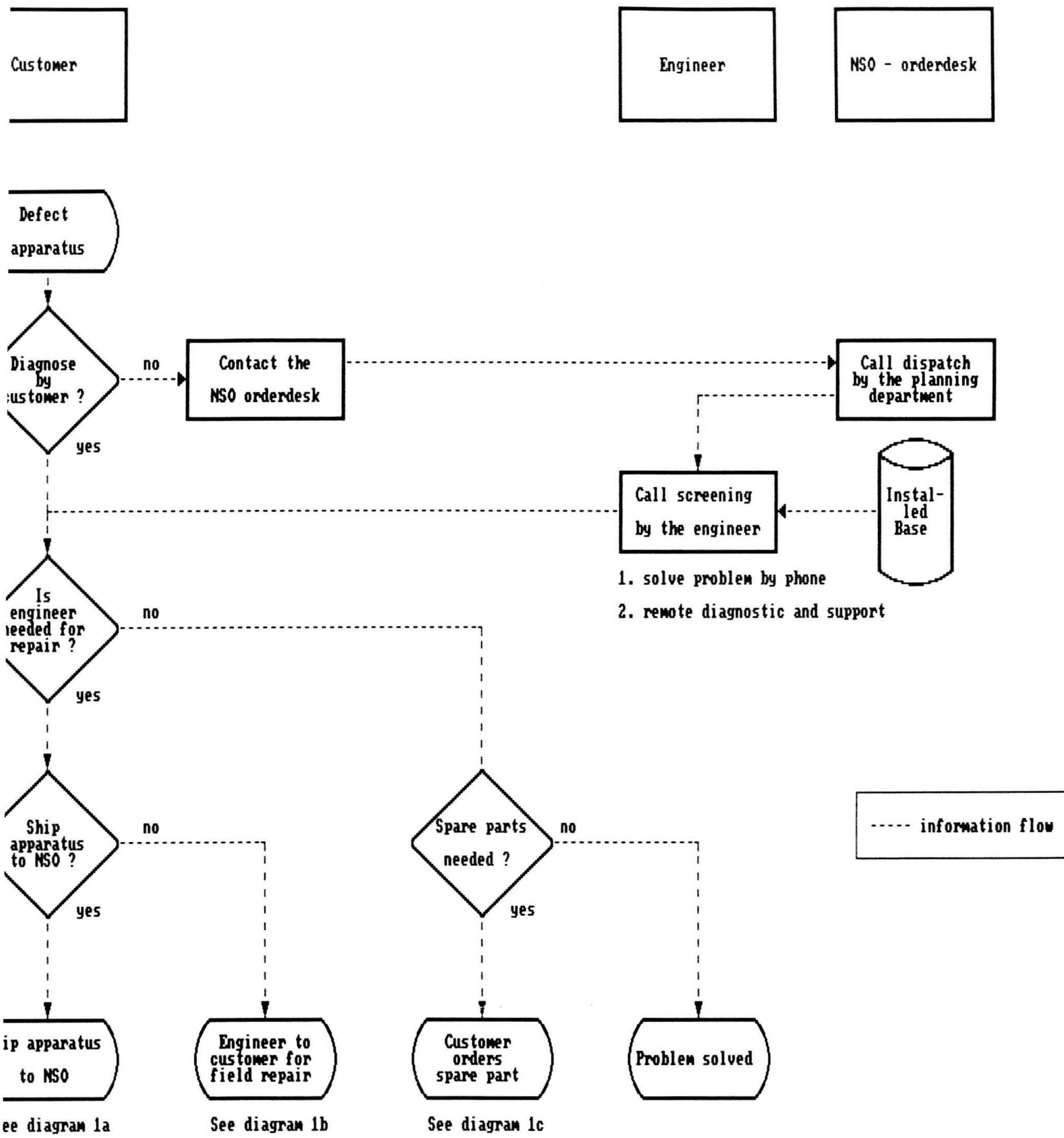
Relation Customer - PCS
There exists no direct flow of defective repairables from the customers to PCS. The flow of new/repaired repairables between PCS and the customers is possible, Direct Delivery.

Relation NSO - PCS **See flow diagram 2**

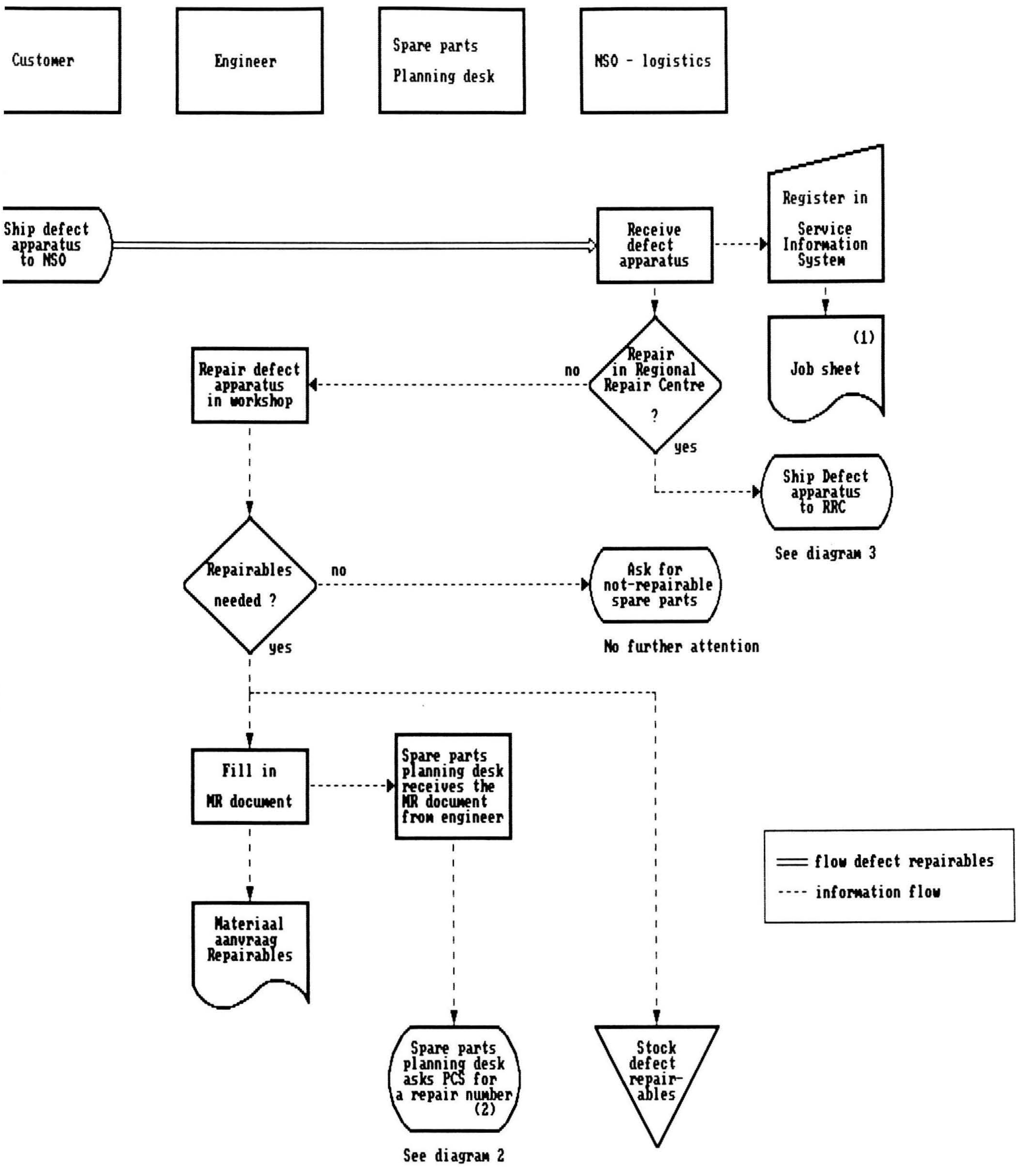
Relation NSO - Regional Repair Centre **See flow diagram 3**

Relation PCS - Repair Centre **See flow diagram 4**

Customer contacts the NSO.



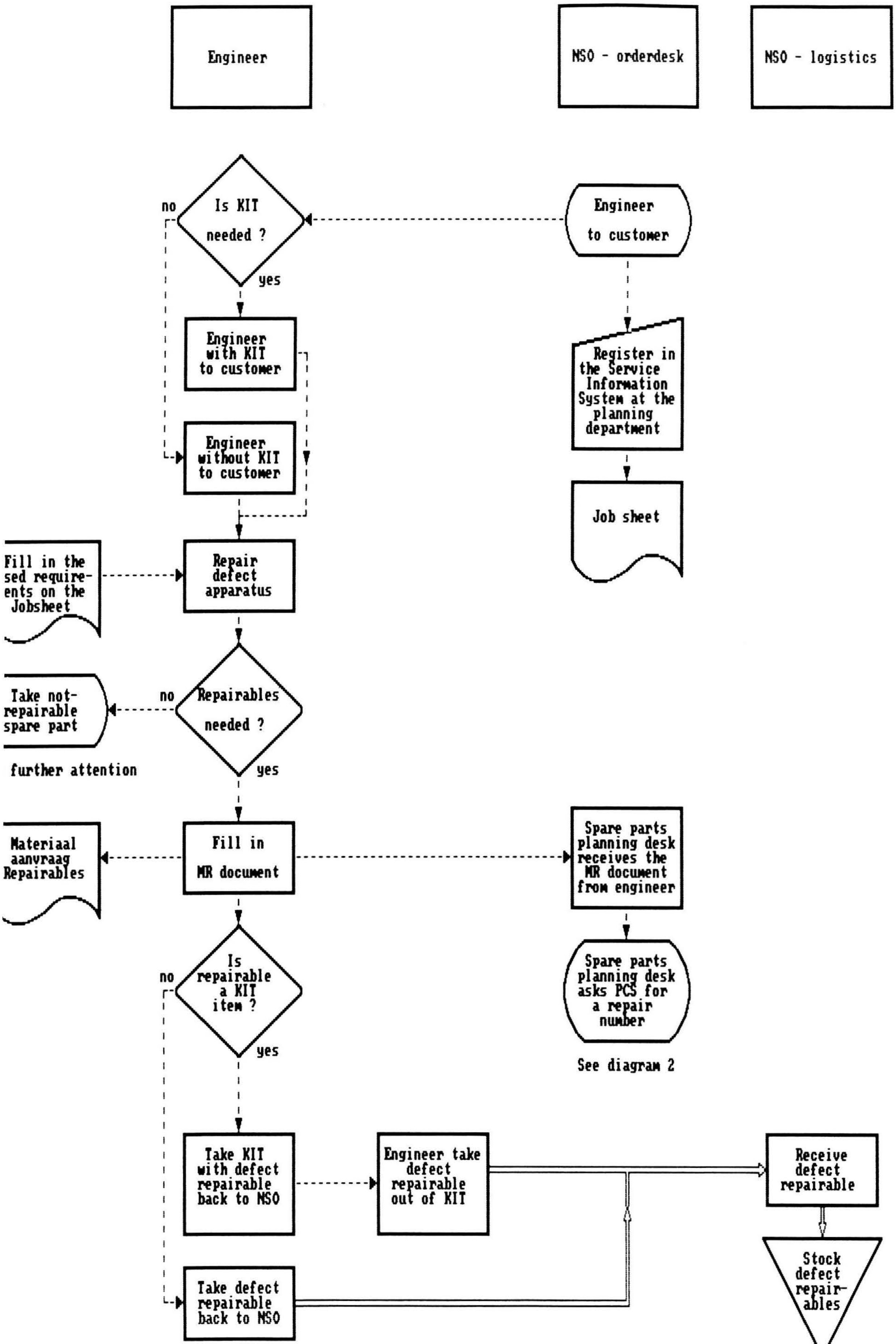
A Customer sends apparatus back to NSO.



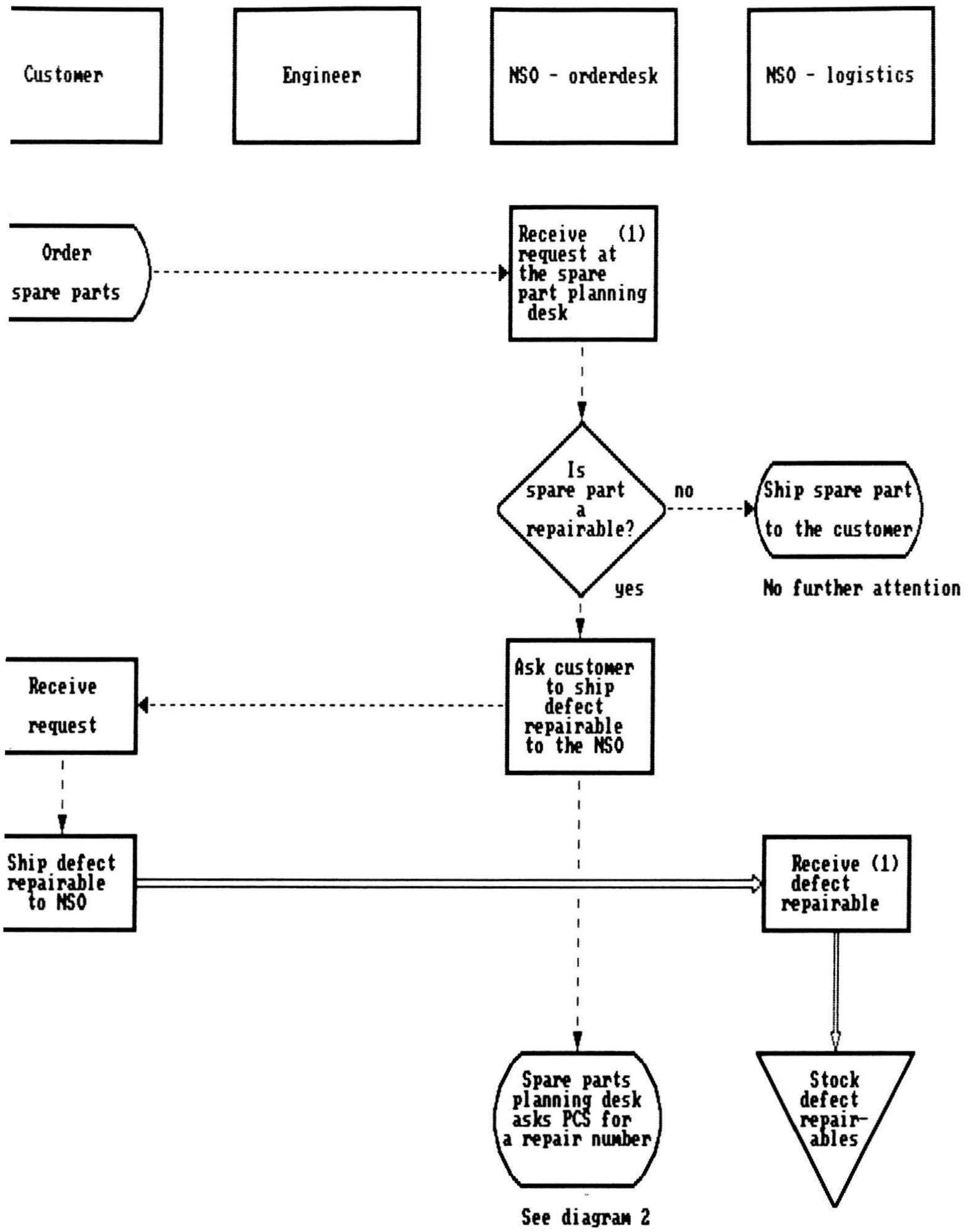
1) - For every repair order, a job sheet has been made. On a job sheet, the engineer register how many hours he worked on the order and which and how many service parts are used.
- Jobsheet consists of 3 forms: 1. Repair sheet
  2. Acknowledgement document for the customer
  3. Product label

2) - the spare parts planning department contacts the customer relations department at PCS in order to get a repair number.
- if the spare parts planning department has an interface with the Main Stockholder System at PCS, the spare parts planning department can even make this request by means of their own computer screen (CICS).

B Engineer to customer.

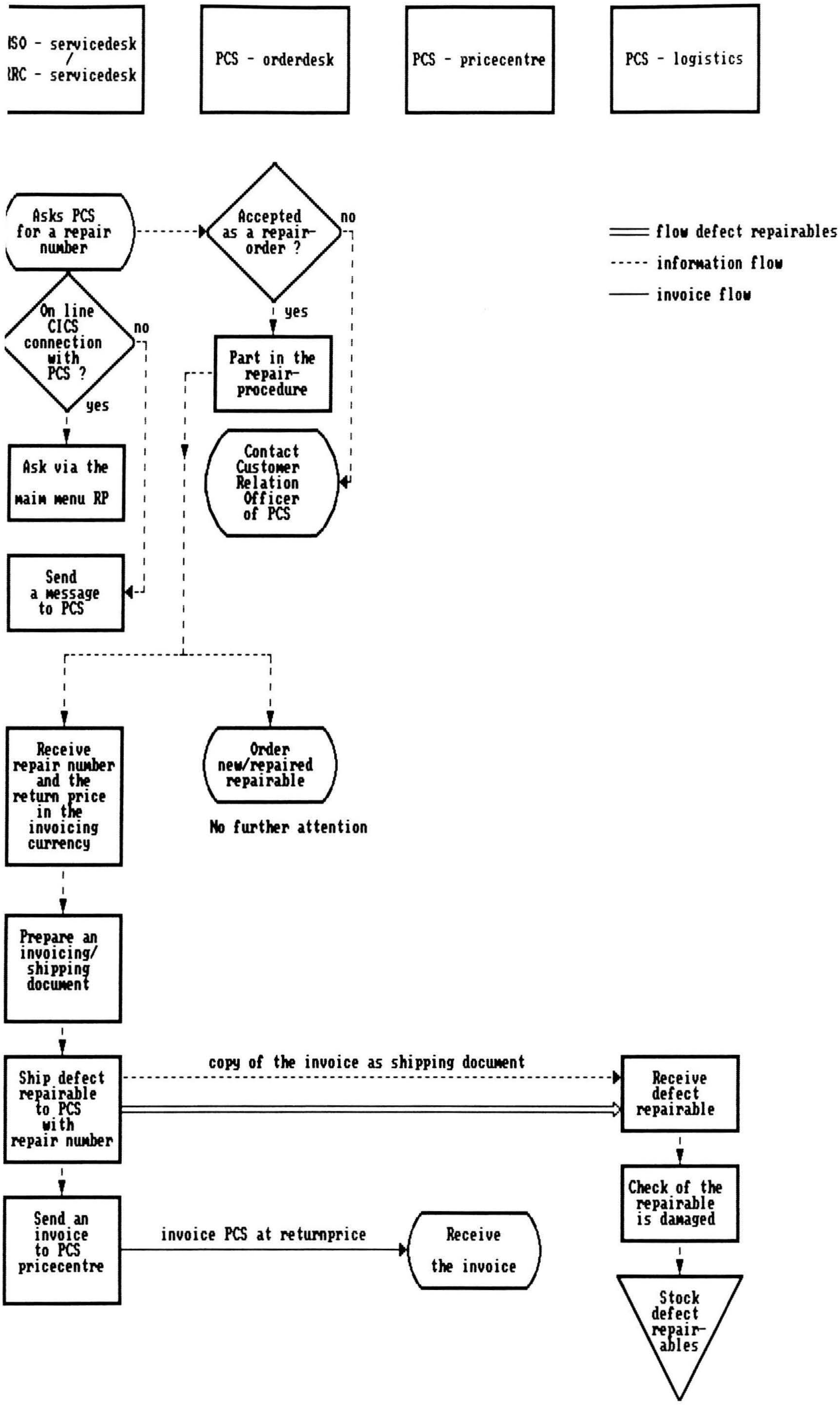


C Customer orders spare part to the NSO.

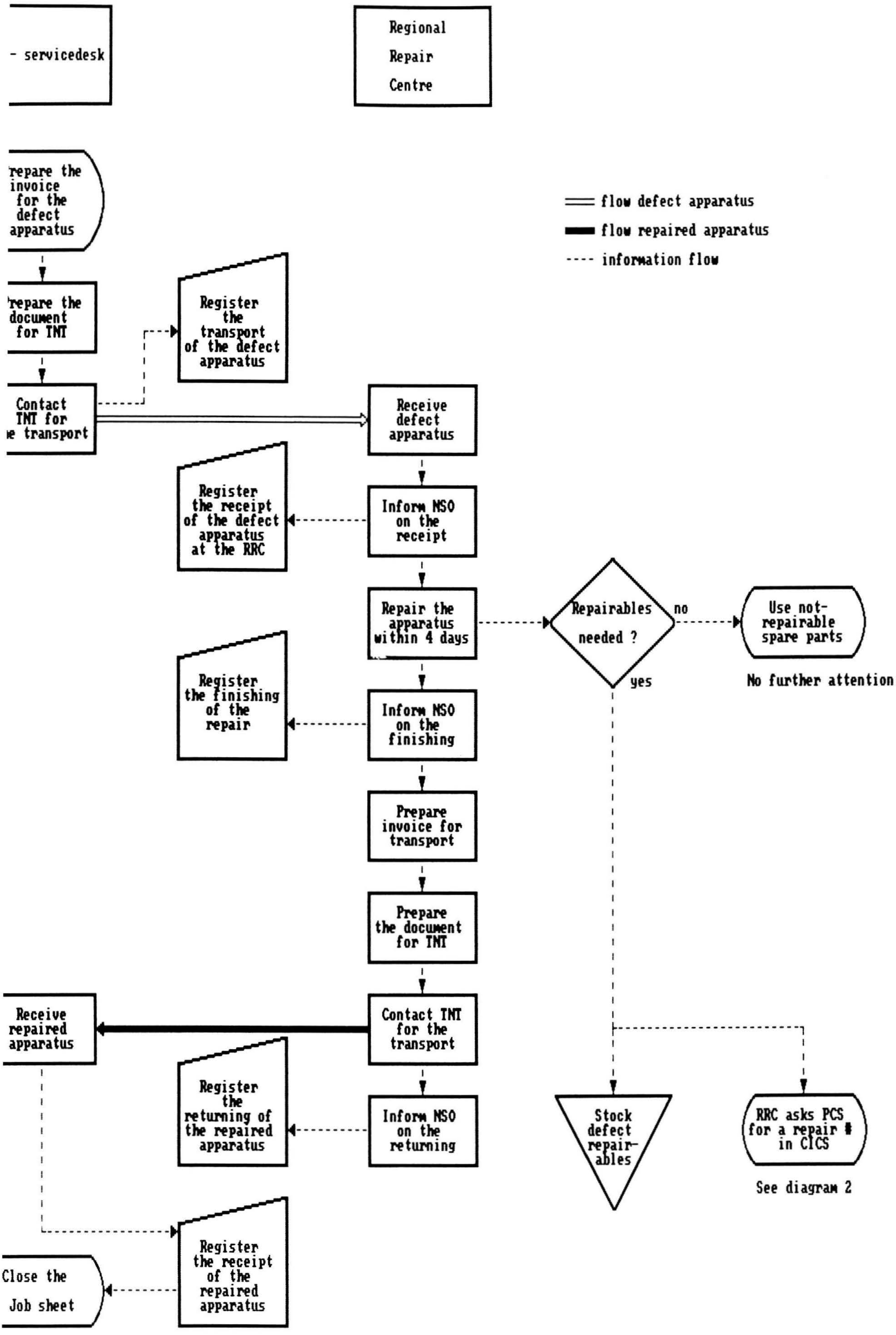


(1) - Sometimes this happens at the same time
- The customers are requested to send back the defect repairables first.
After receiving the defect repairable, the spare parts planning desk sends a new/repaired part to the customer.
Either in case of emergency the customer receives the new/repaired part as soon as possible.

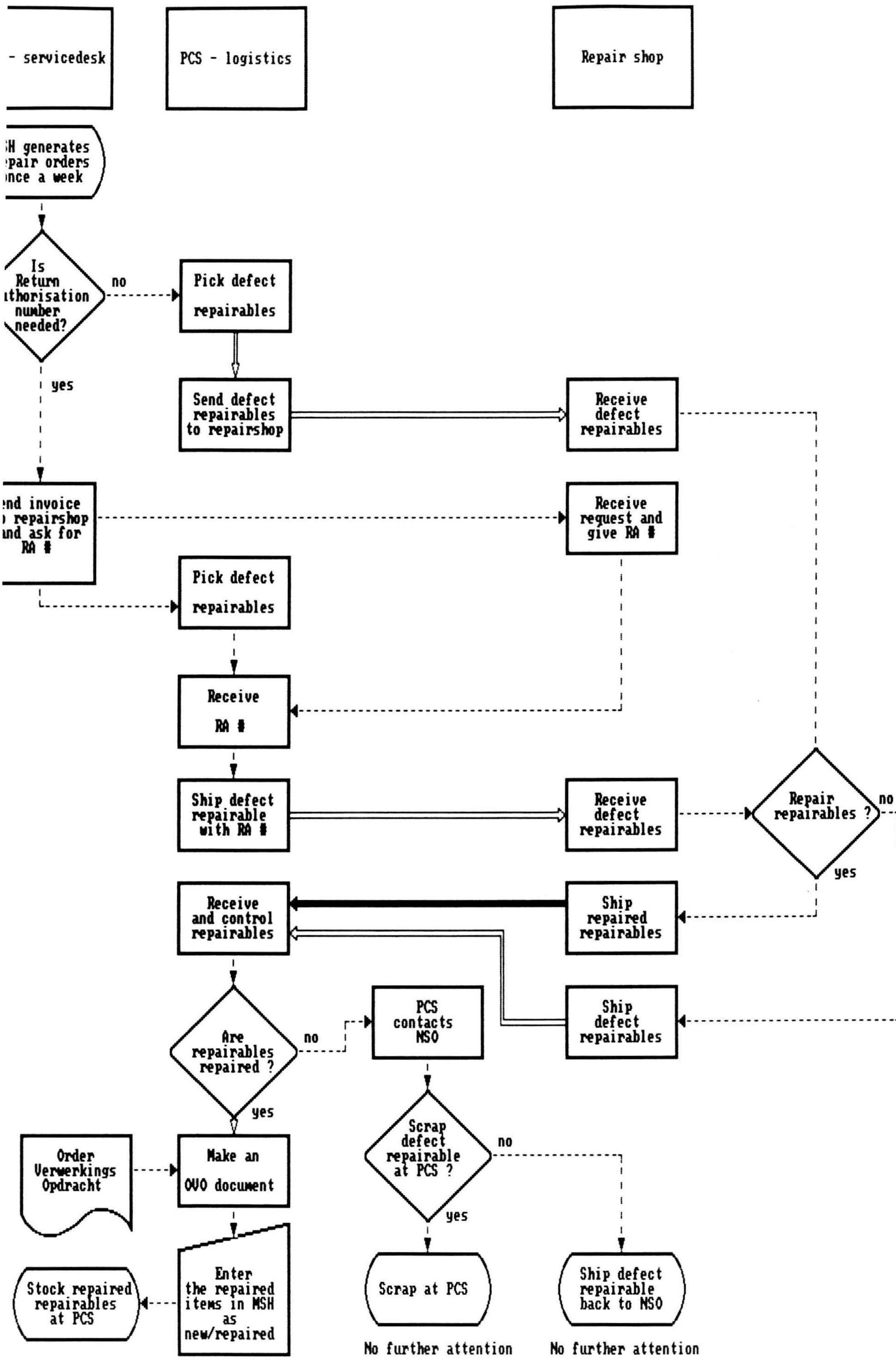
Repairables (normal repair) from NSO's/ RRC's to PCS.



Defect apparatus from NSO to Regional Repair Centre.



Repairables from PCS to the repairshop and back.



Appendix 3: IE spare parts- and repairables movements and stocklevels

Goods movements in 1992	Value (*millions Dfl.)	Number of orderlines	Averaged value per orderline (Dfl)
Receipts of IE spare parts at PCS (from the Supply Centres)	26,9	19,135	1,410.=
Deliveries of spare parts from PCS to the NSO's	18,2	95,839	190.=
Deliveries of repairables from PCS to the NSO's	6	2,908	2,059.=

Stock information 1992	Value (* millions Dfl)
Stock of IE spare parts at PCS (dec 1992)	32,9
Value of obsolete IE spare parts at PCS	19,8
Value of spare parts converted into scrap	3,6

Information from the Main Stock Holder system (PCS reporting). All values are expressed in SSP, to make a comparison of incoming and outgoing goods possible.

Goods movements and stock levels divided per Operating Company

Period: 1992
Amounts in Dutch guilders
Goods movements and stock levels expressed against SSP

Operating Company	A	B	C	D	1	2	3
Analytical X-Ray	155403	879789	1022789	940844	276763	94403	403577
Electron Optics	213292	1517639	1742394	1740521	348773	306051	917839
Power Systems	295	0	0	0	0	0	0
Professional TV test equipment	102	0	0	0	0	0	0
Fluke/ T&M	175661	996741	1073451	1019170	171249	104764	190841
Electronic Manufacturing Technology	472489	351783	379911	206513	172134	2234	187721
Industrial X-Ray	13561	0	0	0	0	0	0
Process and Machinery Automation	14147	220243	337363	387998	54637	25164	85228
Electronic Weighing	21359	201284	220959	297156	36103	154313	86429
Communication and Security Systems	28168	462567	537271	416694	45892	50163	118749
Numerical Control / Grundig	17071	128476	153823	155845	8457	49886	74837
Sundries IE	51239	661096	999460	896881	132503	113460	203831
Total IE	1,162,787	5,419,618	6,467,421	6,061,622	1,246,511	900,438	2,269,052

A: Returns from the NSO's to PCS.
B: Defective repairables from the NSO's to PCS.
(These numbers are original reported against TRPWRD (= SSP - precalculated repair costs))
Precalculated repair costs amount about 30 % of the SSP
C: Flow of defective repairables from PCS to the Repair Centre's for repair.
(These numbers are original reported against TRPWRD)
D: Flow of repaired repairables from the Repair Centre's to PCS.

1: Customer repair balance ; balance of defective parts still to be received from the NSO's, measured dec. 1992.
(These numbers are original reported against RPKWRD (=TRPWRD).
2: Stock of defective repairables at PCS, measured dec. 1992.
(These numbers are original reported against TRPWRD)
3: Outstanding repair balance with the Repair Centre, measured dec. 1992.
(These numbers are original reported against REPWRD (=TRPWRD).

Appendix 4: Direct repair procedures

The OC's Power systems, Professional TV test equipment and Industrial X-ray have no central repair circuit with PCS. The NSO's or the customers have to transport their defective parts direct to the Repair Centre's of the OC's.
In this appendix the central repair procedure of the OC Power Systems and the direct repair procedure of the OC Electron Optics is described.

□ **Regional Repair OC Power Systems in Wavre (B)**
Until 1993 the customers had to ship the defective parts to the NSO's. If the needed tools and test equipment were available, the defective parts were repaired in the NSO work shop (repair circuit 2). Otherwise the defective parts were shipped to PCS.

From the beginning of 1993 Power Systems have decided to repair in Wavre. The customers have to ship the defective parts with a transporter (mostly TNT) to Wavre. After repair, Power Systems sends the repaired parts to the customer. The typical service events are described on the following page.

The reasons for regional repair in Wavre are:

1. Closed Quality Loop; central repair makes it possible to register all the product failures. The registration of the failures (quality reporting) can be used for feedback to the Design-, Production- and Sales department. When the quality reporting is used a process of continuously quality improvement is set in motion.
2. Quality of repair will increase; the frequency of repair of a certain product type is higher, so the experience of repair will increase.
3. Repair throughput time will decrease; customers can ship the defective parts direct to Wavre. The transport time from the customers to the NSO, the material handling time at the NSO and the transport time from the NSO to Wavre no longer exist.
4. Fixed repair prices; in history every NSO set its own prices.
5. Repair tools and test equipment are available on one location, with the result that less investments are needed.

:al service events.

— **Equipment fails**

— **Failure recognized**

— **Call for transport (TNT)**

waiting time

— **TNT arrives and load defective power supply**

averaged 3 days | travel time

— **Receipt of the defective power supply at the goods in department of the Regional Repair Centre**

0.5 days | identification of the delivery of TNT / waiting time for internal transport / transport to the repair cell

— **Receipt of the defective power supply at the repair cell**

input of information in the Service Information System

— **Defective products ready for repair**

waiting time; wait for man capacity/tools capacity/test capacity/spare parts

4 days — **Engineer starts with the repair**

diagnosis
repair
test/calibrate

— **Power supply is repaired/tested**

time between end of test and the input of the information

— **Input in the Service Information System and Output of the documents**

0.5 days | waiting time for transport and internal transport time

— **Receipt of the repaired power supply at the despatch department**

packing and preparing transport documents

— **Call for transport (TNT)**

waiting time

— **TNT arrives and load the repaired power supply**

3 days | travel time

— **Receipt of the power supply at the customers site**

installation

— **Equipment back in use**

□ **Direct repair procedure of the OC Electron Optics (EO)**
The OC EO uses two repair procedures: the PCS repair procedure and the EO direct repair procedure. When spare parts of the OC EO are not introduced in the PCS repair procedure it is possible to ship those spare parts to the Repair Centre of Electron Optics in Acht for repair or modification. The Supply Centre Customer Support department will introduce a spare part in the PCS repair procedure if a spare part type is repaired for more than three times a year.

Difference between the PCS repair procedure and the EO repair procedure
* Charging methods

In the EO procedure, EO delivers a new/repaired part invoiced against repair price. The return shipments from the NSO's to EO are always be done on an uncharged basis.

In the PCS procedure, PCS delivers a new/repaired part invoiced against new price. After receipt of the defective part, PCS sends a credit note to the NSO against the return price.

A problem of the EO procedure is that the defective parts at the NSO's are uncharged, with the result that the NSO's are not motivated to ship every defective part back to EO. The NSO's collect the defective parts and ship them in batches to EO.

* Repair throughput time

The repair through put time of the EO procedure is shorter than the repair throughput time of the PCS procedure. For the EO procedure the material handling time at PCS, the transport time from PCS to EO and the transport time from EO to PCS do not exist.

The reasons for EO to make use of the PCS repair procedure are:

* EO has not enough capacity available for all logistic and administrative activities regarding repairs.
* PCS is a specialist regarding distribution activities; the distribution of the repairables to the NSO's via PCS is cheaper.

Appendix 5: Customer satisfaction survey OC Power Systems in the Netherlands

In the customer satisfaction research process six steps are differentiated.
1. Defining the problem
2. Developing the research set-up
3. Developing the research plan
4. Collecting the information
5. Analysing the information
6. Giving conclusions and recommendations

Remarks:
I will point out that this research has not the status of a regular market research; in this research a few customers were interviewed to get a rough impression about the customer satisfaction regarding the repair procedure of Power Systems.

At the end of the appendix, some results of the customer satisfaction survey carried out by NIPO are mentioned.

1. Defining the problem

Problem area: Central repair OC Power Systems in Wavre (B).

Until 1993 the customers had to ship the defective parts to the NSO's. If the needed tools and test equipment were available, the defective parts were repaired in the NSO workshop. Otherwise the defective parts were shipped to PCS.

From the beginning of 1993 Power Systems have decided to repair all defective parts in Wavre(B). The customers have to ship the defective parts with a transporter (mostly TNT) to Wavre. After repair, Power Systems sends the repaired parts to the customer.

The central "research" question is defined as follows:
Is the central repair set-up of the OC Power Systems, without intervention of the NSO's, also advisable for the other OC's?

This question, can amongst others, be answered by investigating the following topics:

* What is the opinion of the customers about the added value of the NSO's in the return flow of defective repairable spare parts?
* What are the advantages and the disadvantages of the existing central repair set-up from the customers' point of view. Does the existing central repair set-up create enough customer satisfaction?

2. Research set-up

In this phase a method is given how to tackle the defined problem. In case of central repair three main strategies are possible for the return of defective repairable parts:

A. Customer -> NSO -> PCS -> Repair Centre
B. Customer -> NSO --------> Repair Centre
C. Customer ---------------> Repair Centre

For the strategies B and C the strengths and weaknesses will be investigated by interviewing some customers in the Netherlands about the satisfaction regarding the existing central repair set-up.

3. Research plan

In order to collect the right information in an efficient way, a research plan has to be created. It contains a method to be used, to collect the required information and some research questions.

Research method
Some purchasers of some companies in the Netherlands were interviewed by telephone. (The purchasers are the people within the company, who are responsible for the arrival of the repaired parts within the agreed time.) No structured questionnaires were used; the customer interviews were accessible for discussions, where amongst others, the following topics were discussed:

What is the general opinion regarding the central repair procedure of the OC Power Systems in Wavre?

Satisfaction regarding the delivery performance? The actual repair time against the agreed repair time.

Satisfaction regarding the repair quality?

What about the logistic handling activities at the customers' site?

What about the administrative handling activities at the customers' site?

What about the invoicing?

What about the repair price?

What about the communication with the Repair Centre in Wavre? Traceability of the repair status.

Sampling: In consultation with the Power Supply sales manager of the Netherlands, about ten customers were interviewed. He is responsible for drawing a representative sample of customers.

4. Collecting the information

The interviewed Companies

ARA in Aalten; Mr. Stronks.
New repair procedure is terrible!

Too much administrative and logistic actions at the customer site.

The averaged leadtime of repairs is four weeks. The customer is not satisfied; repair time must be shortened.

Invoices arrive about one week too late at the customer. The customer wants the goods flow and the invoices flow to be synchronized, because Ara has to invoice their end users too.

Ara preferred the intervention of the NSO in the repair procedure. Ara ships the defective parts to the NSO in Eindhoven with van Gend & Loos. (Ara does not have to phone van Gend & Loos because they visit Ara every day). At the NSO the required transport forms have to be filled in.

Power Systems Wavre gives no attention to the customer specific reference numbers regarding the repairs. Ara gives every defect power supply a unique number to distinguish the end user's specific parts. At the repair centre in Wavre every part gets a Philips reference number and no attention is paid to the Ara reference number. When Ara receives the repaired power supplies they do not know which part belongs to which customer.

Pie Medical in Maastricht; Mr. Stoelinga.
Too much logistic and administrative actions at the customer site. In former days the "breng en ophaaldienst" of TSPA transported the defective parts to TSPA. TSPA takes care of the transport to Wavre.

No problems with invoicing (after some start-up problems with the repair prices) and no problems with the repair time (the same as before).

The structure is more clear; the company which delivers the parts also repairs the parts.

Peek Traffic in Hilversum; Mr. Coster.
Very unsatisfied with the existing repair procedure. "Do not ask me further questions , I am unsatisfied about everything regarding the central repair in Wavre". Peek traffic is looking for other ways to repair the power supplies!
The communication with Wavre is terrible. For example; on June 11, Peek Traffic sents a fax to Wavre with a request about the status of an emergency repair order. On July 5 they still did not get any reaction from Wavre!

Océ Nederland in Venlo; Mr. Bisseling.
Océ has contracted Frans Maas for transport, so they want the transport to and from Wavre to be executed by Frans Maas. But Power Systems transports the repaired parts with TNT to Océ. It must be regulated by Power Systems Wavre that all transport can be done by Frans Maas.

Océ gets an invoice from TNT.

Too much logistic and administrative actions at the customer site.

Repair price too high; repair costs are almost the same as the cost of a new part.

Philip Industrial Electronics OC Electron Optics; Mr. Dumasy.
Too much logistic and administrative actions at the customer site.

Further no problems.

Philips bedrijf CFT; Mr. Wouters.
Too much logistic and administrative actions at the customer site.

Repair price too high and obscurity about the build-up of the repair costs.

The information provision of changes in the repair procedure is not well managed.

They have to call Wavre for the ready date of the repair; they want Wavre to send a receipt document with the expected ready date to the customer.

Philips Medical Systems XSB; Mr. Torkens.
Too much logistic and administrative actions at the customer site when TNT is used for transport. Medical Systems transports the defective parts with Philips transport.

Satisfied with the repair time; shorter than the repair time in history with intervention of the NSO.

No problems with invoicing (all repairs are carried out in warranty).

No problems with the communication with Power Systems; now it is possible to communicate about the repair status with the engineers in Wavre.

Philips Medical Systems; Mr. van Hunsel.
No problems with the repair times; PMS has enough inventory.

No problems with the repair prices; all repairs are carried out in warranty.

Power Systems invoices PMS while warranty exist.

Financial activities:

1. Repairs carried out in warranty; All return shipments of defective repairables are charged for by Philips supply centres; the defective repairable is charged against the new price of the spare part. There are two money flows: PMS to Power Systems and from Power Systems to PMS.

2. No warranty. Return shipments are uncharged

Ericsson in Rijen; Mr. van Eynatten.
Ericsson sends one power supply to Wavre for repair this year. Ericsson is satisfied; no problems at all.

Philips AG Analytical in Dietikon.
Mr. Nusser sends a fax to Mr. van Mil (Customer Support Electron Optics) with the following message:

The communication with Wavre is at least unpleasant (too long and in a way that is not customer oriented)

Power supplies are sent back in their original state and not customized.

The repair time is too long.

5. Analysing the information

General opinion regarding the central repair procedure
2 customers are very unsatisfied
6 customers have some problems
1 customer is satisfied

Realized repair time
2 customers are unsatisfied; repair time must be shortened.
7 customers have no problems with the existing repair time; the repair time is not so important because the customers have enough inventory.

Repair quality
In general it is hard to make statements about the repair quality.

Administrative- and logistic actions at the customers' site
In general too much actions; the situation with intervention of the NSO is preferred.

Invoicing
4 customers have problems with invoicing; invoices arrive too late at the customer, a customer gets an invoice from TNT and a customer receives an invoice from Power Systems while warranty exists.

Repair price
2 customers have problems with the repair price; repair costs are almost the same as the cost of a new part and obscurity about the build up of the repair costs. The other customers have no problems; all repairs in warranty.

Communication
The advantage of the new repair procedure is that the customer can communicate with the repair shop about the repair status of the power supply. But it is necessary that the contact persons are acting customer oriented; they must understand the problems of the customers and they must be very helpful to solve their problems. Sometimes the language, the lack of customer orientation and the lack of internal communication (see the problem of Peek Traffic!) causes some problems.

Further remarks:
* The information provision of changes in the repair procedure is not well managed.
* Power Systems has to send a receipt document after receipt of the defective parts.
* Power Systems has to give attention to the customer reference numbers.

6. Conclusions and recommendations

* The activities at the customers' site are increased. Some customers are unsatisfied about the new repair procedure; they want the intervention of the NSO.
* The customers are not informed enough about the change of the repair procedure. Only the advantages of the new procedure are mentioned but the customers are not informed about the disadvantages of the procedure and the possible starting problems.
* The new repair procedure is sent to the purchasers of the companies. It is up to the purchasers to distribute the procedure to the despatch officers. In some cases this causes problems; not all people involved with the return shipments of power supplies know the new procedure.
* Power Systems has to send a receipt document to the customer; the customer has to know the defective power supply has arrived at Wavre and the customer wants to know when the power supply will be repaired.
* Power Systems does not know when some power supplies are modified at the customers' site. It must be organized that the repair shop in Wavre knows which parts must be repaired in the original (standard) state and which parts must be repaired in the customized (modified) state.
* The contact persons are not enough customer oriented; problems with the language, not enough experience how to deal with customers.
  - the customer wants the telephone to be answered in his own language
  - the customer wants to know the person he is talking to and this person has to know him.

Recommendations
The goods flow and the invoices flow should be synchronized. If it is impossible, the customer has to know the repair prices so that the customer can invoice his end users.

Pay attention to the repair reference numbers used by the customers.

Power Systems has to regulate the transport in case the customers have their own contracted transporters.

Every customer must get an acknowledgement note after the receipt of the defective parts in Wavre. The customer has to know the product is arrived and the ready date of the repair. It is not tolerable that a customer has to phone about the ready date of his power supply.

When other OC's want to change the repair procedure it is very important that:
1. the customer needs regarding repairs are well known.
2. in case of a changes of existing procedures, the customers have to be well informed about the change and the possible problems.
3. the OC organization is able to work with the new procedure; pay attention to responsibilities of people involved with the repair and pay attention to the way of communicating with the customer.

Results of the IE customer satisfaction survey (carried out by NIPO) regarding Power Systems

Customer service : Satisfactory scores but no strength.
Repair time : Low level of satisfaction.

In the following table the satisfaction scores regarding customer services of Power Systems are shown:

Issues	**Power Systems**	Average competitor	Best competitor	Philips IE
Response time	3.7	3.6	3.7	3.8
Repair time	**3.3**	3.3	3.9	3.7
Availability of spare parts	3.6	3.4	4.2	3.7
Value for money	3.6	3.4	3.7	3.5
Overall satisfaction score customer service	3.7	3.5	3.9	3.8

(Source: Philips IE Customer Satisfaction Survey 1993, carried out by NIPO)

Remarks:
* 1=very bad, 3=not good/not bad, 5=excellent.
* The satisfaction score regarding the repair time in the Netherlands is 3.2.
* 10 % of the customers in the Netherlands are dissatisfied with the repair time; score ≤ 2.

Conclusions satisfaction scores
The position of Philips PS is in the middle of the average and best competitor. The gap between the score of the best competitor is the largest on deliveries and customer service. This is caused by the moderate scores on meeting delivery dates, repair time and availability of spare parts.

Appendix 6: Customer Satisfaction Survey IE 1993

A customer satisfaction survey was carried out by NIPO, the Dutch Institute for Perception Research, on request of the IE Holding during the period January-April 1993. More than 2000 Philips customers in 12 countries have been interviewed about how they perceive the IE products, services and the way of communication. The survey was conducted by telephone. The questionnaire contained the following issues:

1. What comes first to the customers mind when Philips is mentioned.
2. What are the strengths of Philips.
3. What are the weaknesses of Philips.
4. Which other suppliers are used apart from Philips (for the same equipment).
5. What about the customer satisfaction.
6. Reasons for buying from Philips.
7. Suggestions for better support to the customers.

The OC managers are requested to fill in two questionnaires:
1. What is the view of the OC managers about the customers' perception regarding the performance of the aspects mentioned in questionnaire 1.
2. What is the view of the OC manager about the customers' most important suggestions for improvement, as mentioned in questionnaire 2.

So it was possible to compare the real customers' perception with the opinion of the OC managers about the customers' perception.

Results and conclusions of the customer satisfaction survey in general
The information about the customer satisfaction is available on OC and country level.

Only the results and the conclusions regarding customer service are mentioned in more detail here.

1. The opinion about Philips (spontaneous remarks)
Spontaneous remarks were asked about the products, employees, service, price and others. Most of the remarks are related to the products. The second category of spontaneous reactions is customer service (technical assistance, quality of the customer service, response time and the after sales services).

2. Strengths
In terms of strengths the rank order is: 1. products; 2. customer service; 3. and employees.
The quality of the customer service is mentioned as a specific strength, but not by customers in all OC's.

3. Weaknesses
The rank order of the weaknesses is 1. products 2. service 3. price 4. employee.
It should be noted however, that the products, customer service and the employees are much more often mentioned as a strength than as a weakness. The most frequently mentioned weaknesses regarding customer service is the response time, which is too long.

4. Other suppliers
No general information.

5. Customer satisfaction
The following aspects have been discussed: products, deliveries, salesforce, customer service and the documentation.

To set priorities for improvement, "more important" and "less important" aspects must be distinguished.

Impact scores were determined by calculating the correlation between the overall satisfaction scores and the satisfaction scores for each of the key issues, on basis of multivariate statistical analyses. Aspects with a high correlation have a relatively high impact of improvement. In practice low scores on high impact aspects means high priority for investment.

The impact scores of overall satisfaction for each key issue on Philips overall satisfaction is shown in the following table:

Key issue	Impact (index)
Product	100
Customer service	66
Sales force	62
Documentation	44
Delivery	38

The impact scores of the specific attributes on the overall area satisfaction of customer service is shown in the following table:

Customer service attributes	Impact
Response time	100
Value for money	84
Availability of spare parts	48
Repair time	47

The satisfaction with customer service and documentation is lacking on the satisfaction with the product, deliveries and sales force.

The satisfaction scores of Philips IE are shown in the following table:

Key issues	Satisfaction scores (*)
Products	4.0
Deliveries	4.0
Salesforce	4.0
Customer service	3.8
Response time	3.8
Repair time	3.7
Availability of spare parts	3.7
Value for money	3.5
Documentation	3.8
Overall score	3.8

* 1=very bad, 3=not good/not bad, 5=excellent.

The aspects regarding customer service with 10 % or more dissatisfied customers are:
- meeting delivery dates.
- repair time
- availability of spare parts
- value for money in customer service

6. Reasons for buying from Philips
The most important reason for buying from Philips is the product. EO and AXR distinguish themselves from other OC's because of the fact that their customers often mention the customer service as a reason for buying from Philips.

7. Suggestions for improvement
Customers need more information on the product and more in general " a Philips that is listening better to its customers".

(Source: Philips Industrial Electronics Customer Satisfaction Survey 1993)

Appendix 7: Issue frequency Group

From the point of view of inventory management it is important to know whether one is dealing with a fast or slow moving article. Decisions in the field of trend determination, forecasting, frequency of inventory status determination etc. are considerably influenced by the demand rate of the article. For every IFG the risk of obsolescence is determined.

The moving rate of a spare part is dependent on the number of orderlines per year. A spare part of which 300 parts are sold per year, for example, may have either a slow-moving or fast-moving character, completely dependent upon the number of orderlines per year. The part has a slow-moving character if the 300 pieces are sold on one orderline in the year. On the other hand the part will have a fast-moving character if the 300 pieces are sold on 100 orderlines in the year.

Within Philips IE , empirically issue frequency groups (IFG) have been determined. The IFG indicates to what extent a part is slow or fast moving.

Every three months (quarterly run) the expected number of issues during the coming 12 months will be calculated as follows:

0.5 * last calculated number of year-issues + 2 * counted number of issues during the last 3 months

Depending on the result of the above mentioned formula, the code number will be assigned to one of the IFG's.

The following information is given per IFG:
- issues per year
- percentage of the IE spare parts
- risk of obsolescence
- maximum age of a forecast expressed in weeks

IFG	Issues per year	% of the IE spare parts	Obsolescence risk (%)	Forecast age (weeks)
1	> 48	0.5	5	4
2	25 - 48	0.9	10	4
3	13 - 24	2.4	20	4
4	5 - 12	7.5	25	17
5	2 - 4	12.7	45	26
6	0 - 1	75.9	75	26

Appendix 8: Customer Order Decoupling Point concept

An important topic in determining the planning and control concept is the position of the Customer Order Decoupling Point (CODP) in the entire supply chain. The CODP divides the "customer order driven" part of the control from the "planning and forecast driven" part of the control. For every product market situation a CODP position can be determined. In case of the IE spare parts supply the most occurring position is at PCS level, see figure A8.1.

The CODP location is in general the same location as the main stock point. For every product market combination a CODP location can be defined.

In the supply of the IE repairable spare parts, the following five locations of the CODP can be distinguished, see figure A8.2.

Decoupling point 1
"Deliver from car stock". High usage and low valuable spare parts are stocked in the cars of the service engineers. Some "total stop items", these are crucial for the uptime of the installation, are also stocked in the cars.

Decoupling point 2
"Deliver from local (NSO) stock". The parts are stocked at the NSO and can be distributed to the engineers and the customers. Fast moving spare parts and "total stop items" are stocked at the NSO.

Decoupling point 3
"Deliver from central (PCS) stock". The parts are stocked at PCS and can be distributed to the NSO's, the engineers and to the customers. All slow moving and fast moving parts are stocked here.

Decoupling point 4
"Deliver from the Supply Centre". Some repairable spare parts are not introduced yet in the PCS repair procedure. When these spare parts are needed they will be delivered from the stock at the Supply Centre.

Decoupling point 5
"Repair on customer order". In the above mentioned four locations, field exchangeable units are delivered from a stock point. The defective parts are exchanged by new/repaired ones. On this location only customized repairs are kept. The customer wants his own part back after repair.

The objective of the IE spare parts supply (and especially for the slow moving parts) is to realize a shift of the CODP from the national stocks (DP 2) to central stock in Eindhoven (DP 3).
In order to make this possible acceleration of the logistic process (ordering spare parts, material handling in the central warehouse and physical distribution) is necessary. The advantages of the DP shift are:

1. Inventories are less expensive when stocked at the beginning of the supply chain (lower added value).
2. Inventories are not geographical specific yet at PCS stock level.
3. Less safety stock; only a safety stock at the central stock point is required which results in lower inventory costs, lower warehouse costs and a lower obsolescence risk.

In general the obsolescence risk of the inventory is the biggest at DP 1. At DP 5 there is no obsolescence risk but it is important to realize an agreed delivery performance (repair within agreed time frame) and the risk exists the fixed repair price will be exceeded.

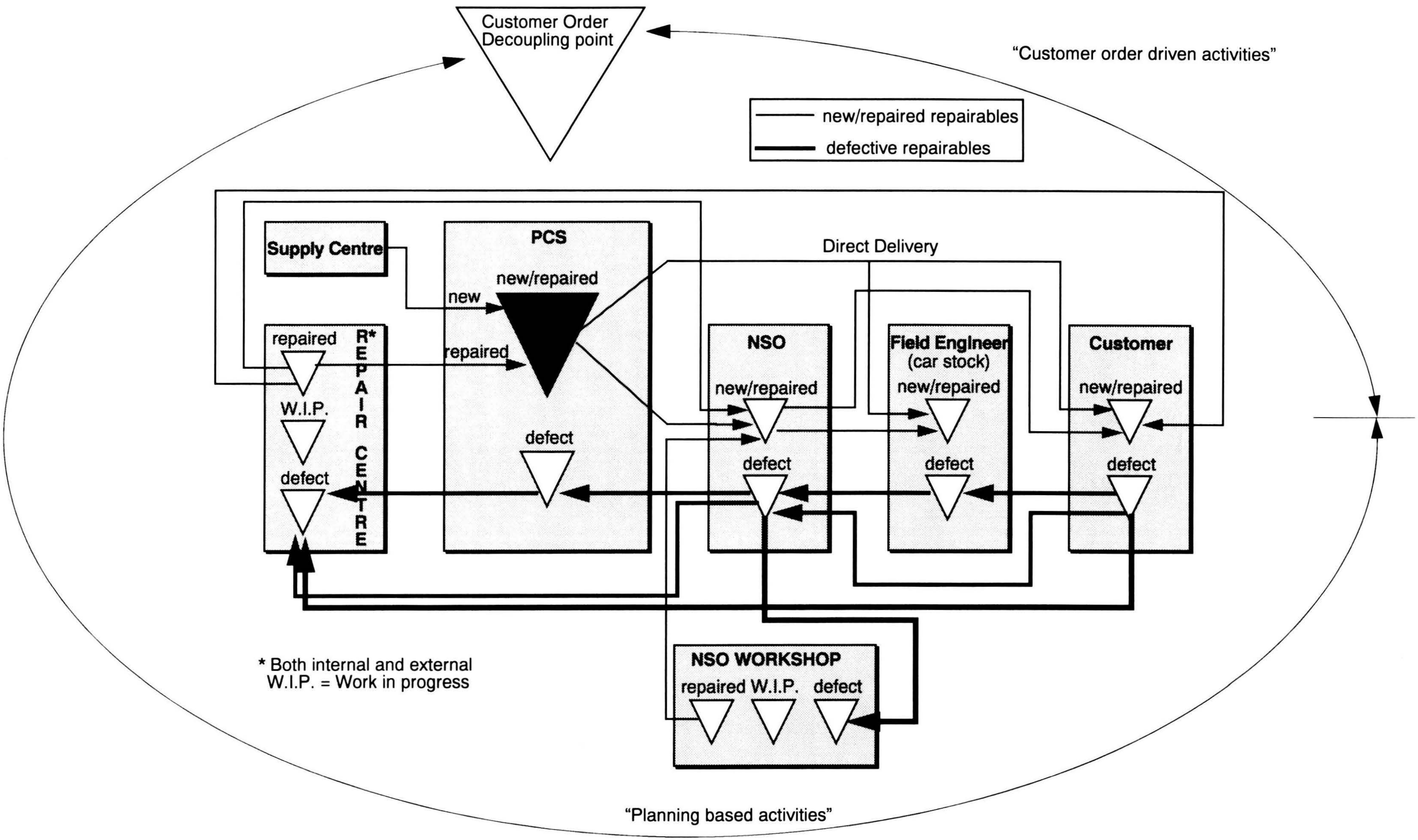


Figure A8.1 Customer order decoupling point

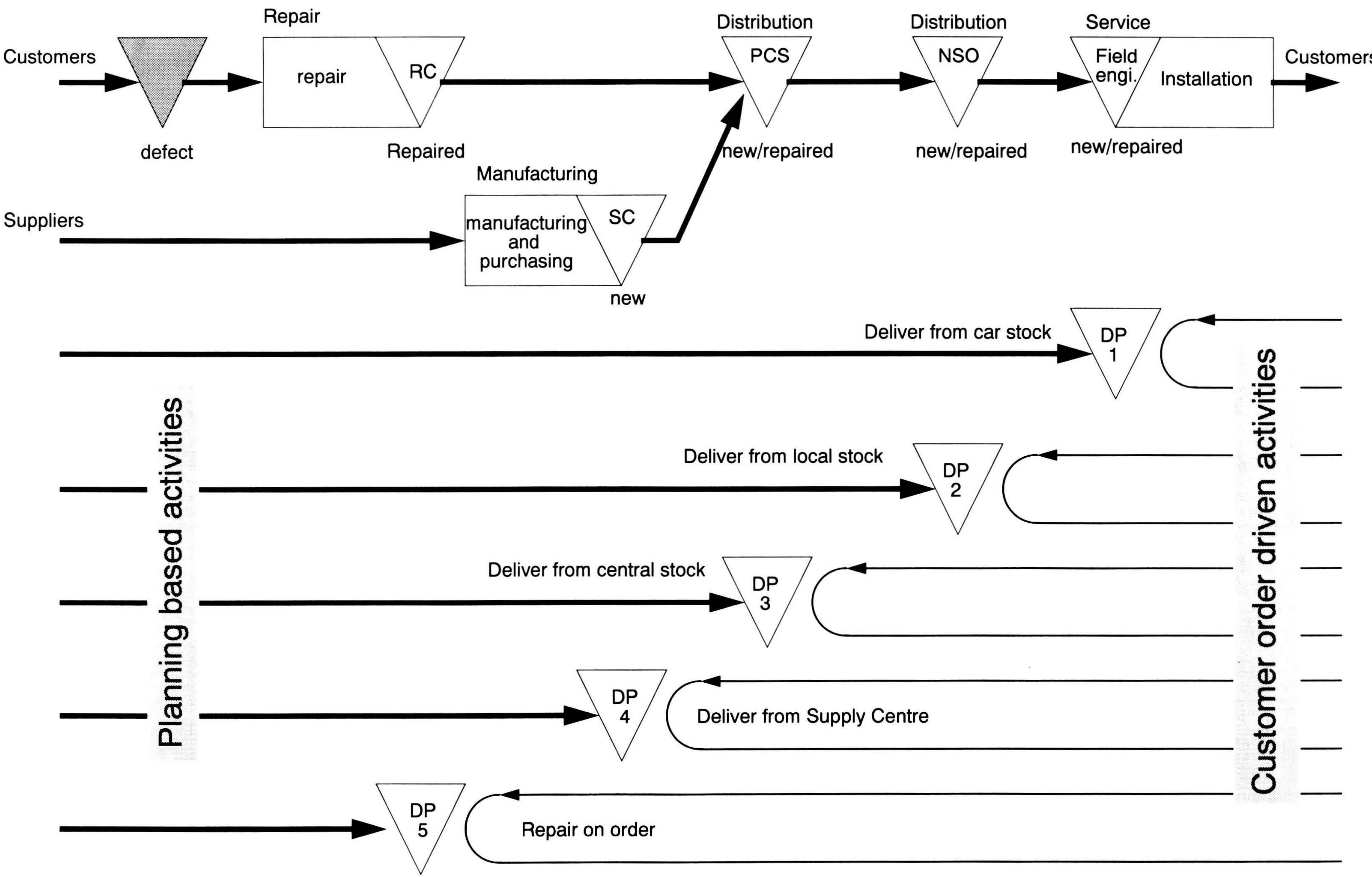


Figure A8.2 Customer order decoupling points

Appendix 9: Conditions to return repairables

When a repairable part is offered for central repair, this part has to meet the following repair conditions:

Packing
If possible, the parts must be returned in the original packaging. If the packing material is not available any more, adequate packing must be provided locally.

All printed circuit boards and other sensitive electronic devices must be packed in ESD (anti static) packing material.

All parts, should always be packed individually in order to avoid damage during transport.

Labels and shipping documents
The parts offered for repair should always be labelled. This label is a must in order to offer the repair department the necessary information to realize a time- and cost efficient repair. For this reason the **repair label** must contain at least the following information:
- service 12 NC of the repairable
- serial number of the repairable
- name of the sender
- failure description
- repair authorization number

On each outer carton the **address label** should be glued.

The sender must always send a copy of the **invoice** as shipping document with the shipment.

Appendix 10: Total cycle time of a repairable spare part

By defining the total cycle time the in figure 1 depicted logistic structure is the basis.

The total cycle time of a repairable spare part consist of the following parts:

I_t	:	**Installation time**;	the period an item is installed in a system at the customers' site.
F_t	:	**Field time**;	the time interval between the field service engineer replaces the defective item and the NSO receives the defective item.
N_t	:	**NSO time**;	the time interval between the NSO receives the defective item and the central stock point of defective items (PCS or a Repair Centre) receives the defective item.
S_t	:	**Stock time**;	the time interval between the defective part is stocked and the Repair Centre receives the defective item for repair.
R_t	:	**Repair time**;	the time interval between the Repair Centre receives the defective item and the repaired item is stocked at PCS.
P_t	:	**PCS time**;	the period a new/repaired item is stocked at PCS.
D_t	:	**Delivery time**;	the delivery time from PCS to the NSO or to the customer.

- The total cycle time (CT_t):

$$CT_t = I_t + F_t + N_t + S_t + R_t + P_t + D_t.$$

Remark: The total cycle time (minus the installation time) must be minimised.

- The repair loop leadtime (L_r):

$$L_r = F_t + N_t + S_t + R_t.$$

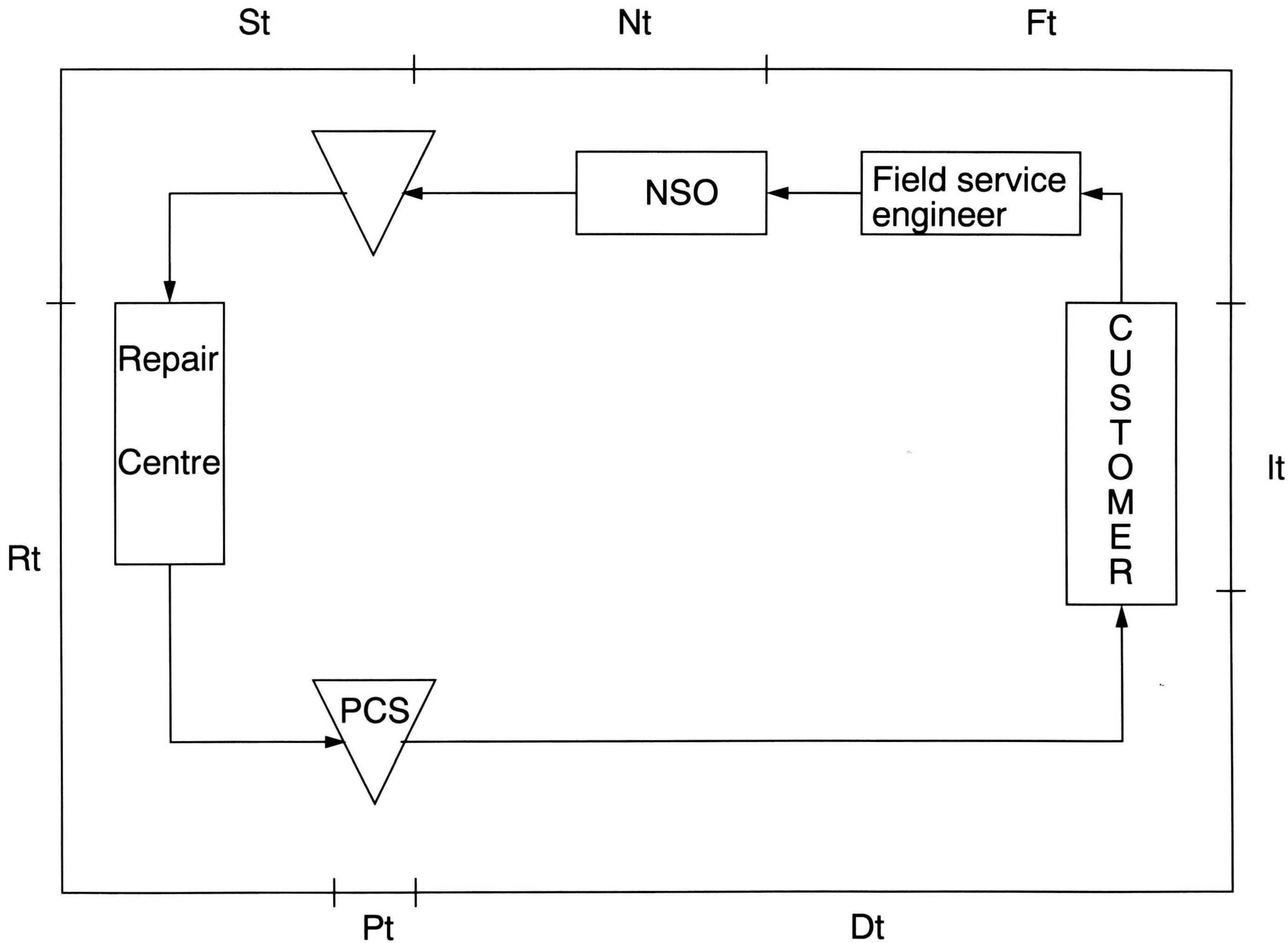


Figure A10.1 Repair pool leadtime

Appendix 11: A deterministic inventory model for repairable items

The mathematical derivation of the economic order quantities is described here. The derivation is made by Schrady [10]. The following parameters are used.

Notations

C summation of inventory carrying, purchase ordering and repair induction costs per unit time.
C_p fixed ordering cost per purchase order.
C_r fixed repair induction cost per repair batch.
D demand per unit time.
L_p purchase leadtime.
L_r repair loop leadtime, see appendix 10.
n number of repair inductions.
Q_p purchase order quantity.
Q_r repair batch quantity.
r recovery rate as a fraction of D.
R_p purchase reorder point.
R_r repair reorder point.
V_n value of a new/repaired spare part.
V_d value of a defective part.
h inventory holding cost as a percentage of spare part value per unit time.
T cycle time, time between successive purchase quantity arrivals of new parts at PCS.

Assumptions

- Demand is deterministic and known
- Items are recoverable at a fixed and known rate
- A repaired item is as good as a new one
- Repair capacity is unlimited
- Purchase and repair leadtimes are fixed and known
- The cost parameters are known

The mathematical expressions are concerned figure A11.1

Expressions are developed for the total cost per cycle and the cycle time in order quantities and known constants. From these expressions, the total cost per unit time is derivated which is differentiated with respect to Q_p and Q_r to imply the two optimal order quantities.

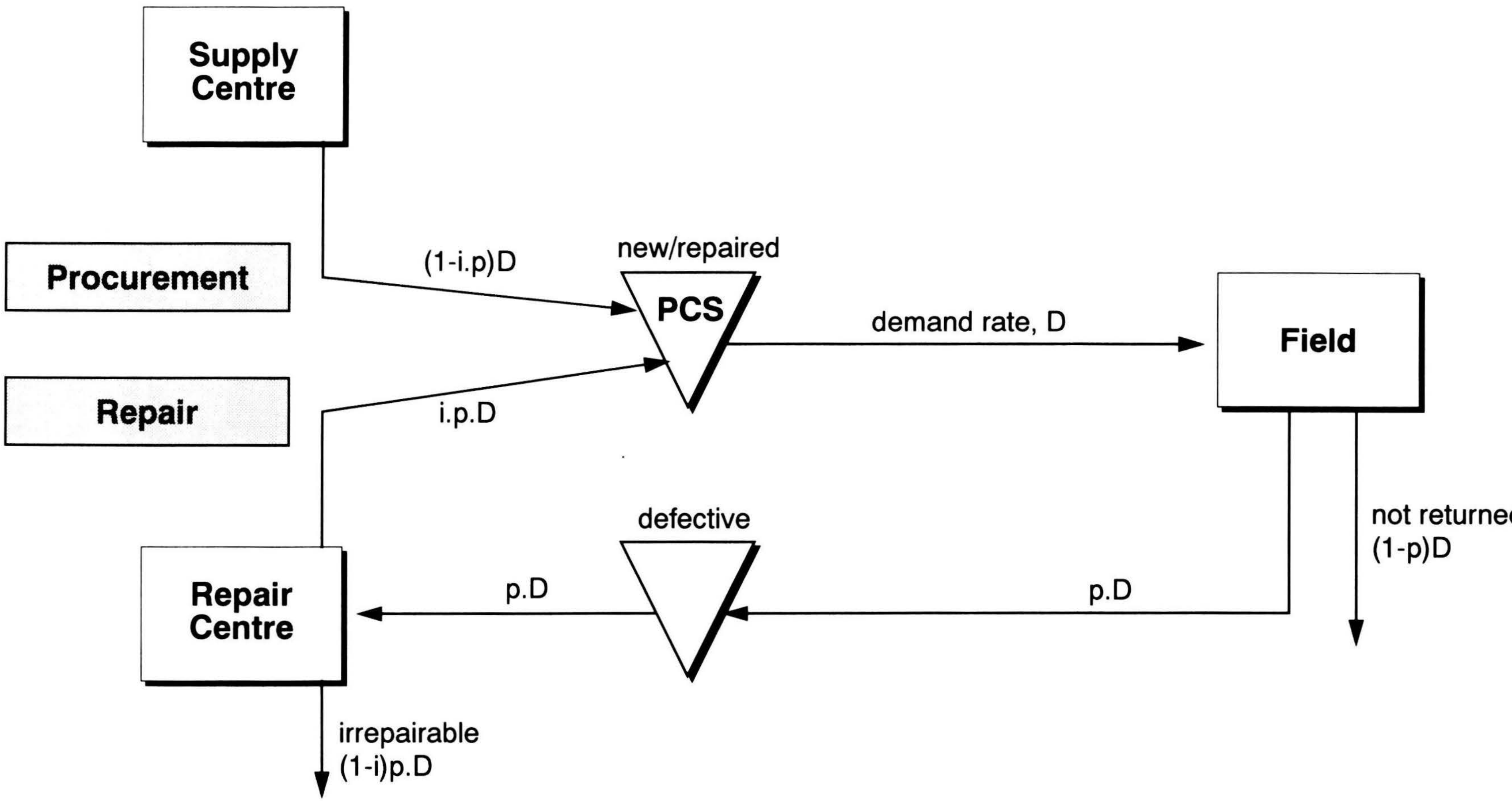


Figure A.11.1 Repair inventory structure

□ The time period during which repair releases are suspended (T_a).

$$T_a=\frac{Q_p+Q_r}{D} \quad (1)$$

□ Nett loss of defective parts per repair cycle.
As result of the positive scrap rate not all defective parts from the field are repaired. The net loss of defective parts per repair cycle, the time between two repair releases, is given by the rate of accumulation (rD) multiplied by the repair cycle time (Q_r/D) minus the repair batch quantity: i.e.,

$$(rD)\frac{Q_r}{D}-Q_r=Q_r(1-r)$$

□ n : number of repair inductions per cycle.
Now, the first repair batch after the repair release are resumed takes the amount Q_r from the defective parts inventory. The subsequent releases cause a nett reduction of only Q_r(1-r) parts. Thus the amount of defective spare parts available for the (n-1) releases (all but the first) is rDT_a - Q_r, or after simplification, Q_r(r-1) + rQ_p. Dividing the last expression by Q_r(1-r) n is determined.

$$n=(\frac{r}{1-r})\frac{Q_p}{Q_r}$$

□ The system cycle time (T).

$$T=\frac{nQ_r+Q_p}{D}$$

or

$$T=\frac{Q_p}{(1-r)D}$$

□ The total cost per cycle.

The total cost per cycle are:
1. Stock holding cost of new/repaired parts;
2. Stock holding cost of defective parts;
3. Purchase order cost;
4. Repair release cost.

Qr	:	repair batch quantity
Qp	:	procurement order quantity
T	:	cycle time
D	:	Average demand per year
r	:	recovery rate as a fraction of the demand

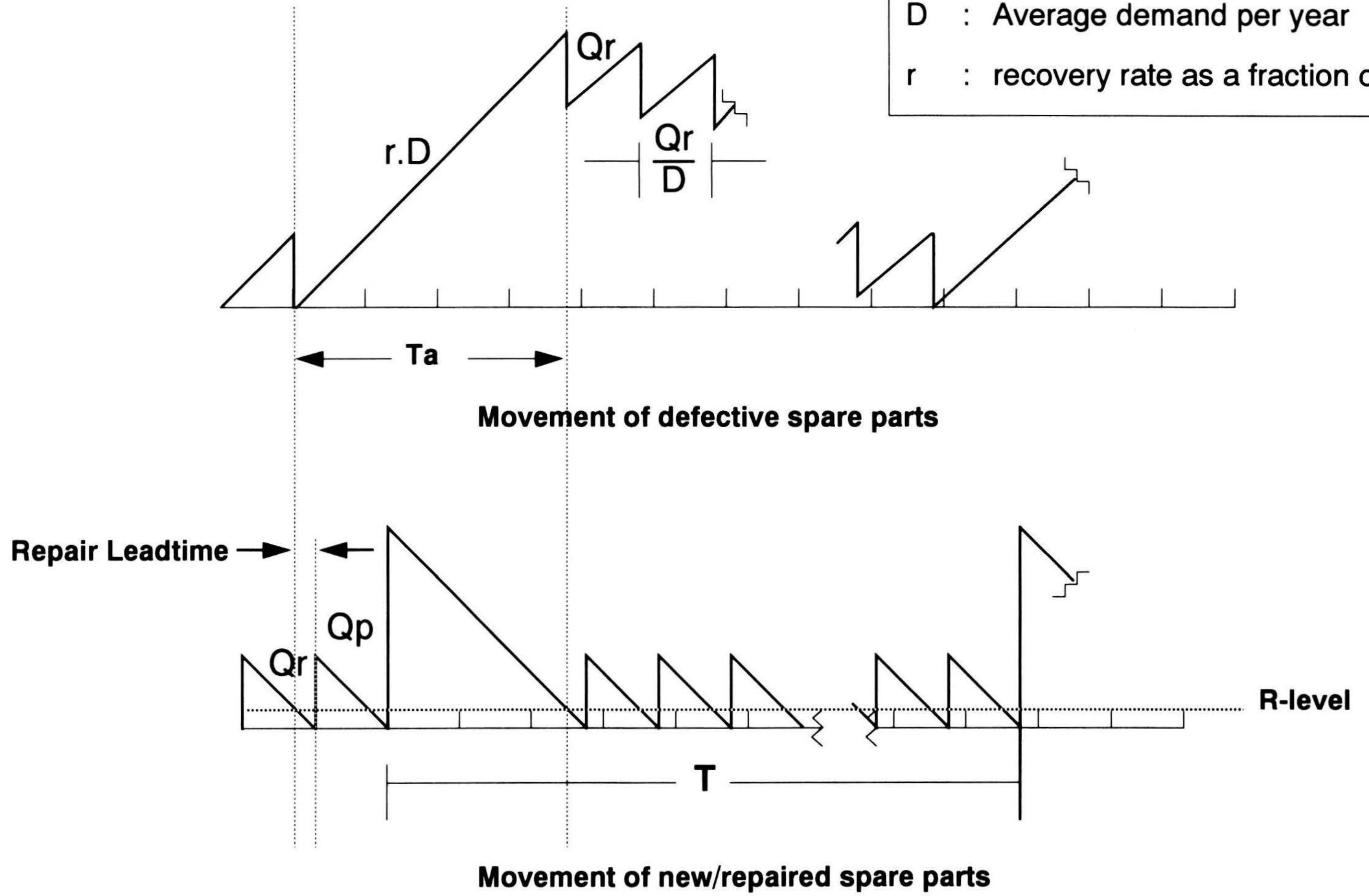


Figure A.11.2: Movement of spare parts

1. Stock holding cost of new/repaired parts

The stock holding cost is determined by multiplying the area under the new/repaired parts curve with the holding cost per part. The area under the new/repaired curve is obtained as the sum of n triangles of height Q_r and base Q_r/D, plus the triangle of height Q_p and base Q_p/D. See figure A11.2. The area under the new/repaired parts curve, over one complete cycle, A_n, is then:

$$A_n=\frac{1}{2D}*(\frac{r}{1-r})*[Q_pQ_r+(\frac{1-r}{r})Q_p^2]$$

The stock holding cost of new/repaired parts is A_n * h * V_n.

2. Stock holding cost of defective parts

The area under the defective parts curve is divided into a triangle and (n-1) trapezoids. The area of the triangle is 1/2 *T_a(rDT_a), which when using formula 1 reduces to (r/2D)*$(Q_p + Q_r)^2$. The total area of the (n-1) trapezoids is determined in terms of a quantity L, the smallest height of the largest trapezoid. The larger heights are related to the smaller heights by the constant rQ_r. Thus the lower heights are related by the constant Q_r(r-1). It may be verified, using the above relations and the relation that the sum of the first k-1 positive integers equals k(k-1)/2, that the total area of k such trapezoids is given by the expression

$$\frac{kQ_r}{2D}[2L+rQ_r-(k-1)Q_r(1-r)].$$

Finally, for the model, L=rDT_a-Q_r, which reduces to rQ_p-Q_r(1-r) after utilizing formula (1). The total area under the defective parts curve, A_d, is then after simplification,

$$A_d=(\frac{1}{2D})(\frac{r}{1-r})[Q_pQ_r+Q_p^2].$$

The stock holding cost of defective parts is A_d * h * V_d.

3. Purchase order cost (C_p).

4. Repair release cost (nC_r).

The total cost per cycle

$$\frac{TC}{cycle}=hA_nV_n+hA_dV_d+C_p+nC_n$$

Using the expressions for n, A_n, A_d and dividing formula 7 by the system cycle time, T =(Q_p + nQ_r)/D = Q_p/D(1-r), gives the objective function; the total cost per unit time expression

$$\frac{TC}{t}=\frac{C_pD(1-r)}{Q_p}+\frac{C_rrD}{Q_r}+\frac{hV_nr}{2}[Q_r+(\frac{1-r}{r})Q_p]+\frac{hV_dr}{2}[Q_p+Q_r].$$

The optimal order quantities are obtained by setting the partial derivatives, with respect to Q_p and Q_r, of formula 8 equal to zero and solving the resulting equations. The optimal order quantities are
The order quantities Q_p and Q_r are determined, minimizing the total cost measured on an annual basis, while satisfying a certain service degree. The total cost (TC) is the sum of the stock holding cost, purchase ordering cost and repair induction cost. The total cost function per unit time is expressed in terms of the two order quantities and known constants. The cost function is partial differentiated with respect to Q_p and Q_r to determine the two optimal order quantities.

The optimal order quantities are

$$Q_p = \sqrt{\frac{2*C_p*D*(1-r)}{h*(V_n*(1-r)+V_d*r)}}$$

$$Q_r = \sqrt{\frac{2*C_r*D}{h*(V_n+V_d)}}$$

Appendix 12: Performance indicators

Per entity the performance parameters and indicators are defined.

1. Output of the service engineers: the service engineer is obliged to return the defective part within the agreed time.

Performance parameters	Performance indicators
Service engineer return time	The number of days elapsed between the replacement of the defective part at the customers' site and the receipt of the defective part at the NSO office.
Service engineer return balance	The number of defective parts located at the service engineers' car or home.
Service engineer back order performance	The number of days elapsed between the replacement of the defective part and the moment of measuring.

2. Output of the NSO: the NSO is obliged to return the defective part within the agreed time.

Performance parameters	Performance indicators
Flow of defects send by NSO to PCS	The number of the defects returned in a certain time interval.
	The value of the defects returned in a certain time interval.
Internal throughput time	The number of working days elapsed between the arrival of the defective part at the NSO and the shipment of the defective part to PCS.
Return time	The number of weeks elapsed between the request of the repair authorization and the arrival of the defective part at PCS.
NSO return balance	The number of the defective parts still located at the NSO's.
	The money value of the defective parts still located at the NSO's.
Backorder performance	The number of weeks elapsed between the request of the repair authorization number and the moment of measuring.
Batching	The number of pieces per repair authorization number.

3. Output of PCS: PCS is responsible for on time and correct deliveries given the set targets.

Performance parameters	Performance indicators
Stock of defective parts	Measured in times supply
	Measured in value.
Internal throughput time	The number of days between the receipt of the defective part at PCS and the date of dispatch of the defective part to the repair address.
On time delivery; the delivery within the agreed time	The number of parts delivered within the agreed time in relation to the total number of deliveries.
Correct delivery; the delivery of the right part	The number of correct deliveries to repair addresses in relation to the total number of deliveries.
Flow of defects shipped from PCS to a Repair Centre	The number of the defects shipped from PCS to a Repair Centre in a certain time interval.
	The value of the defects shipped from PCS to a Repair Centre in a certain time interval.

4. Output of the Repair Centre: the Repair Centre is obliged to repair the defective part within the agreed repair time.

Performance parameters	Performance indicators
Flow of defects shipped from the Repair Centre to PCS	The number of the repaired parts shipped from a Repair Centre to PCS in a certain time interval.
	The value of the repaired parts shipped from a Repair Centre to PCS in a certain time interval.
Repair balance	The number of the parts located at the Repair Centre.
	The money value of the parts located at the Repair Centre.
Repair time	The number of weeks between the receipt of the defective parts and the despatch of the repaired parts to PCS.
On time delivery	The number of parts repaired in the agreed repair time in relation to all the repairs.
Backorder performance	The number of weeks between the agreed repair ready time and the moment of measuring.

Remark: Concerning the performance indicators which are expressed in weeks or hours, the average and the deviation can be calculated.

Appendix 13: Product characteristics of the EO repairables

The repairable parts are categorized. The classification in categories is based on the Dutch guilders-usage value (value times the annual usage), see table 1, and the repair leadtimes, see table 2. In table 3 both criteria are used to classify each part.
In this appendix also information is given about the repari code, IFG, Repair Centre and the forecasted repairs per repairable spare part.

Table 1: The Dfl.-usage value (*1000)

Dfl. usage (* 1000)	# of parts	% of parts	% of Dfl. usage
0 - 25	204	91.8	32
25 - 50	10	4.5	22
50 - 75	3	1.4	13
75 - 100	2	0.9	10
100 - 125	2	0.9	14
125 - 150	1	0.5	9
Totals	222	100	100

Remarks: The Dfl. usage value is calculated, by multiplying the P_{tr} with the SSP per item.

The total forecasted annual Dfl.-usage value is *f* 1,573,000.=

Table 2: The repair leadtime distribution

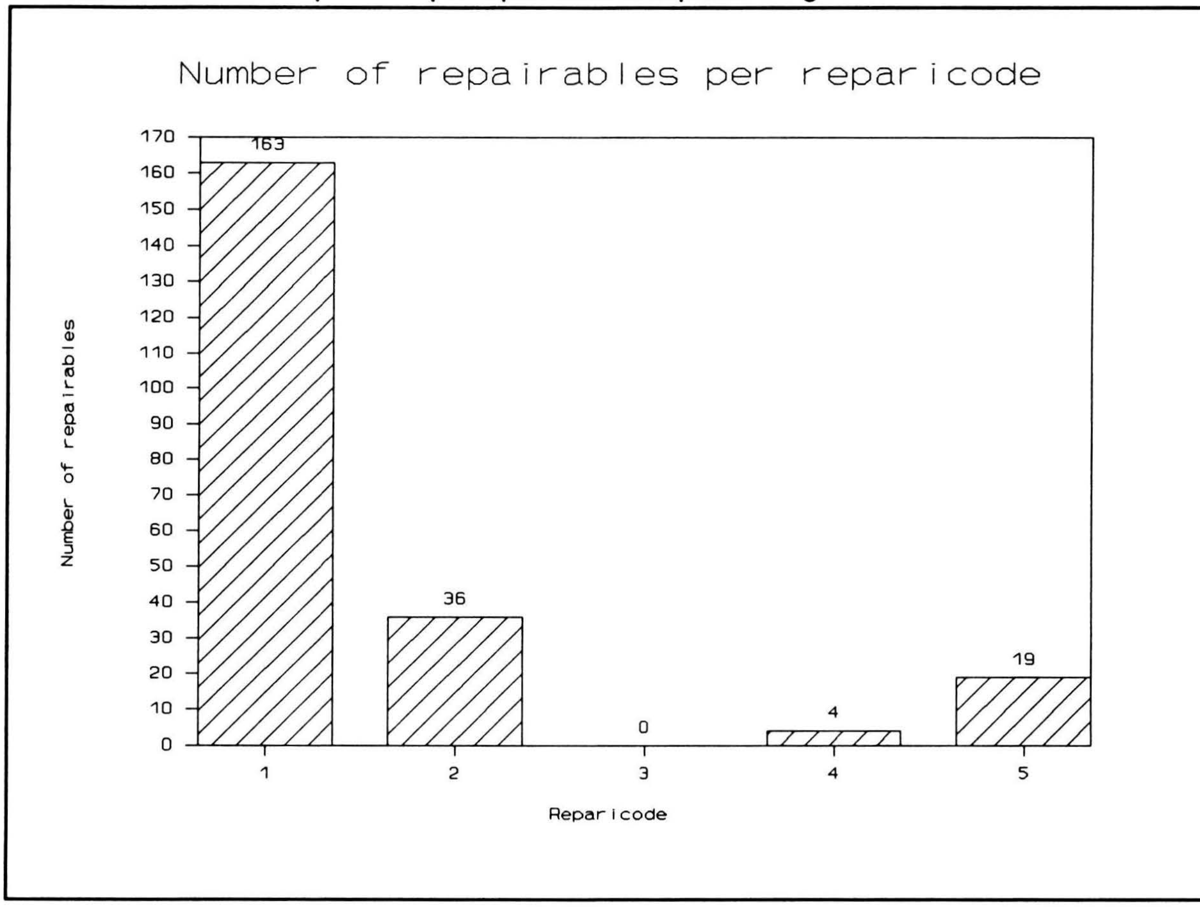
Lead times (weeks)	# of parts	% of parts	% of Dfl. usage
0 - 5	19	8.5	4
6 - 10	70	31.5	38
11 - 15	66	29.7	16
16 - 20	63	28.4	40
21 - 25	3	1.4	2
26 - 30	1	0.5	0
Totals	222	100	100

Table 3: The number of items classified by the Dfl. usage and the repair leadtimes

Dfl. Usage (* 1000)	**Repair leadtimes**						
	0-5	6-10	11-15	16-20	21-25	26-30	Totals
0-25	19	63	63	56	2	1	204
25-50		3	3	3	1		10
50-75		2		1			3
75-100	1			1			2
100-125		1		1			2
125-150				1			1
Totals	20	69	66	63	3	1	222

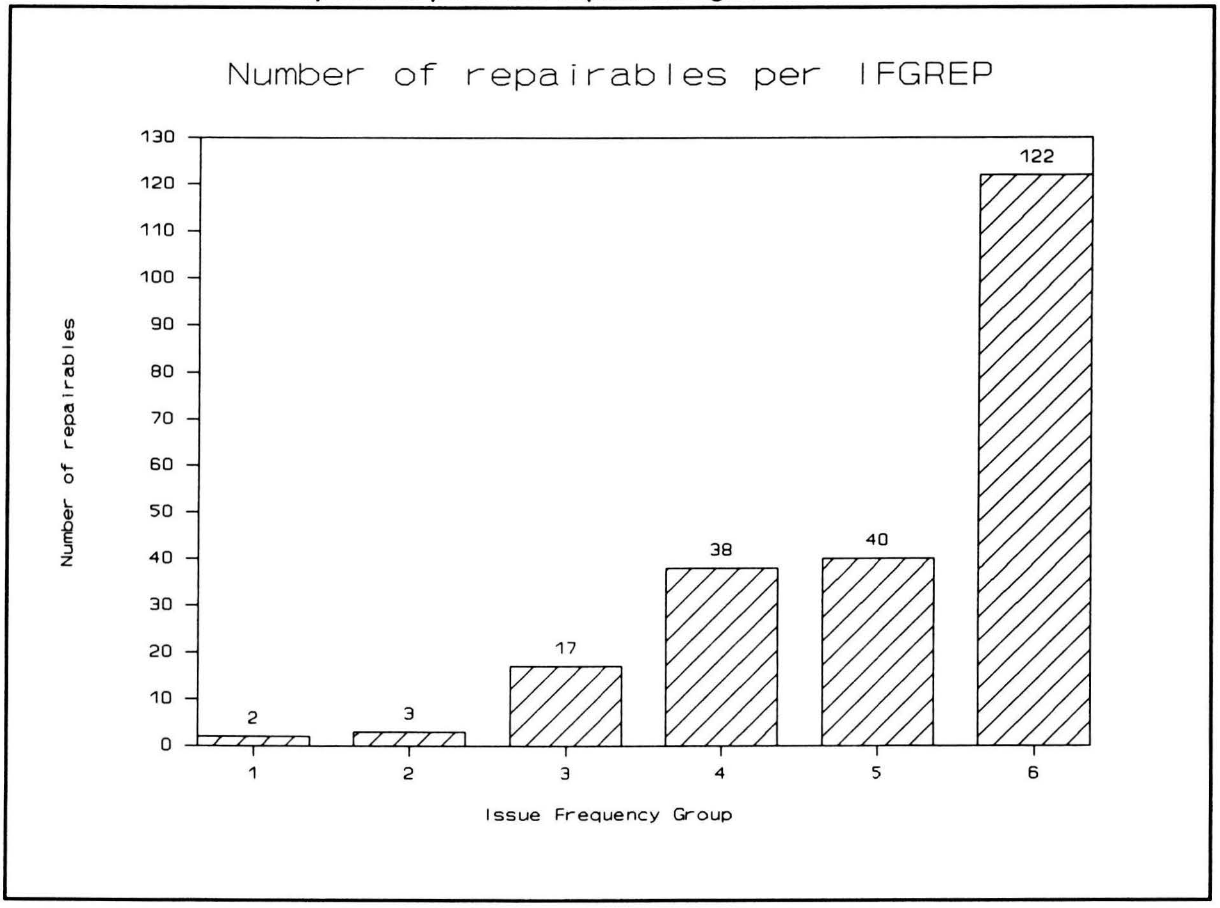
The code number of the repairable spare part in the last Dfl. usage category is 5322 218 40041. That is a HT Generator with repair address Philips Almelo.

- The division of the repairables per repari code is depicted in figure 1.



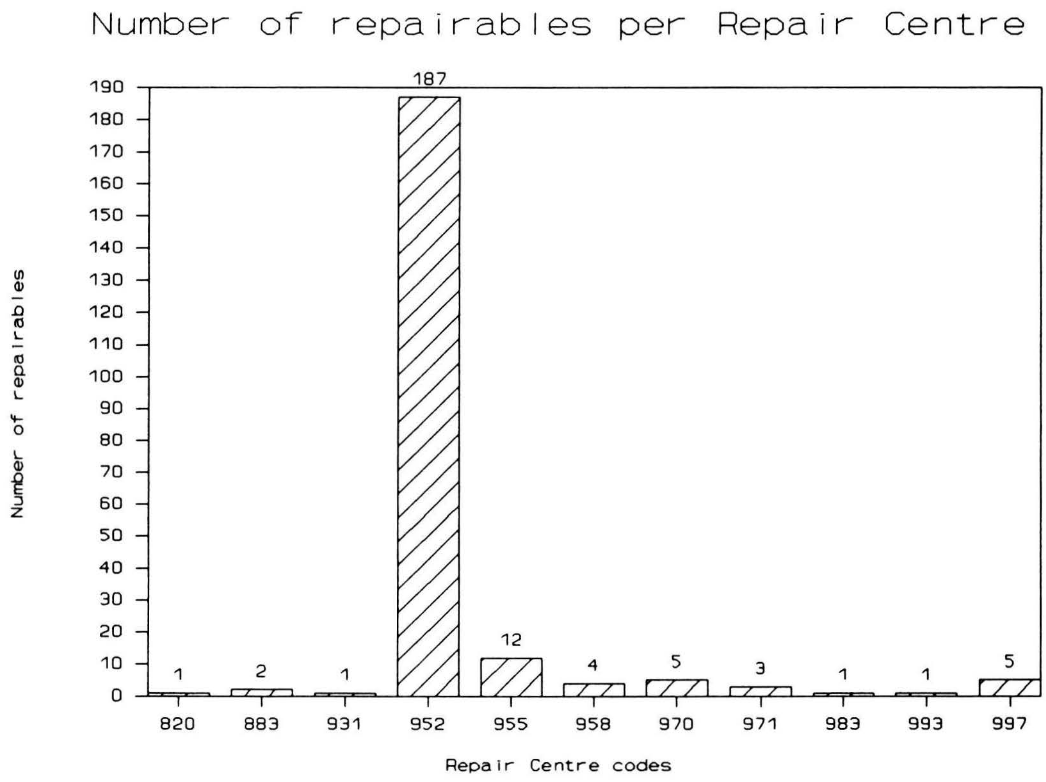
Remark: 16% of the repairables are customised (repari code 2)

☐ The division of the repairables per IFG is depicted in figure 2.



Remark: About 73% of the repairables have a slow moving character (IFG 5 and 6)

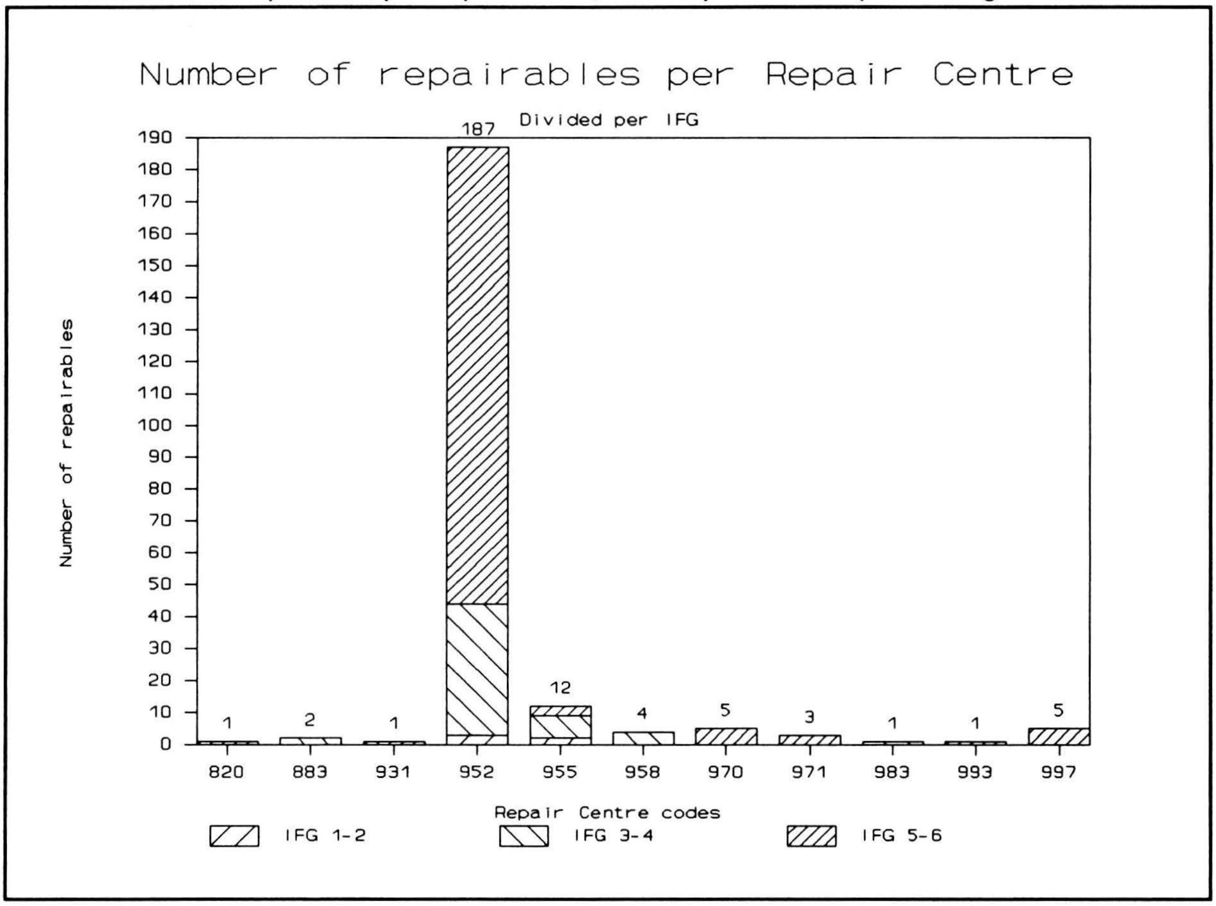
- The division of the repairables per Repair Centre is depicted in figure 3.



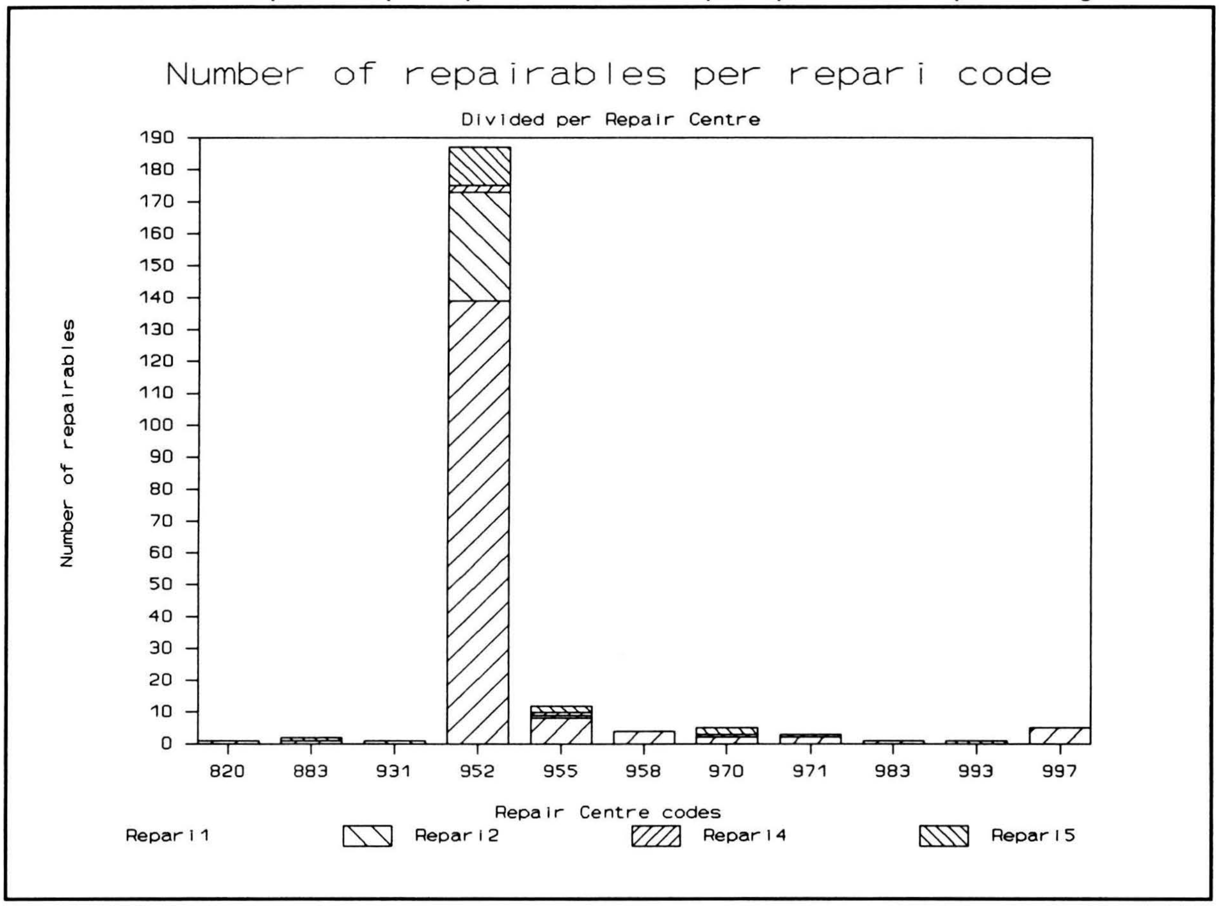
The explanation of the Repair Centre code numbers is showed table 4.

Code number	Repair Centre
820	Intel
883	Balzers
931	Evlieb
952	Philips Electron Optics
955	Philips Power Systems
958	Philips Almelo
970	De Jong
971	TSPA
983	Leybold
993	Haefely
997	Scantech

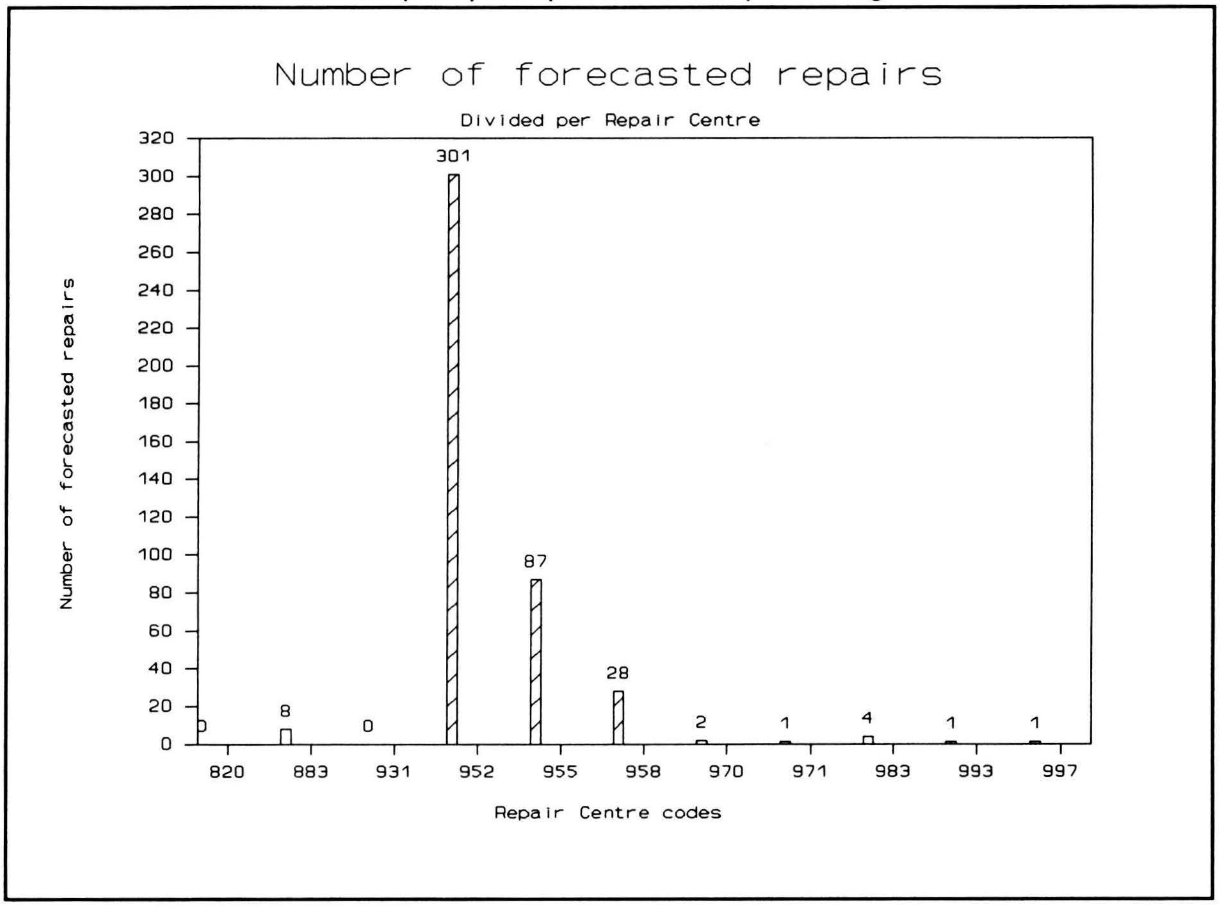
- The number of repairables per Repair Centre, divided per IFG is depicted in figure 4.



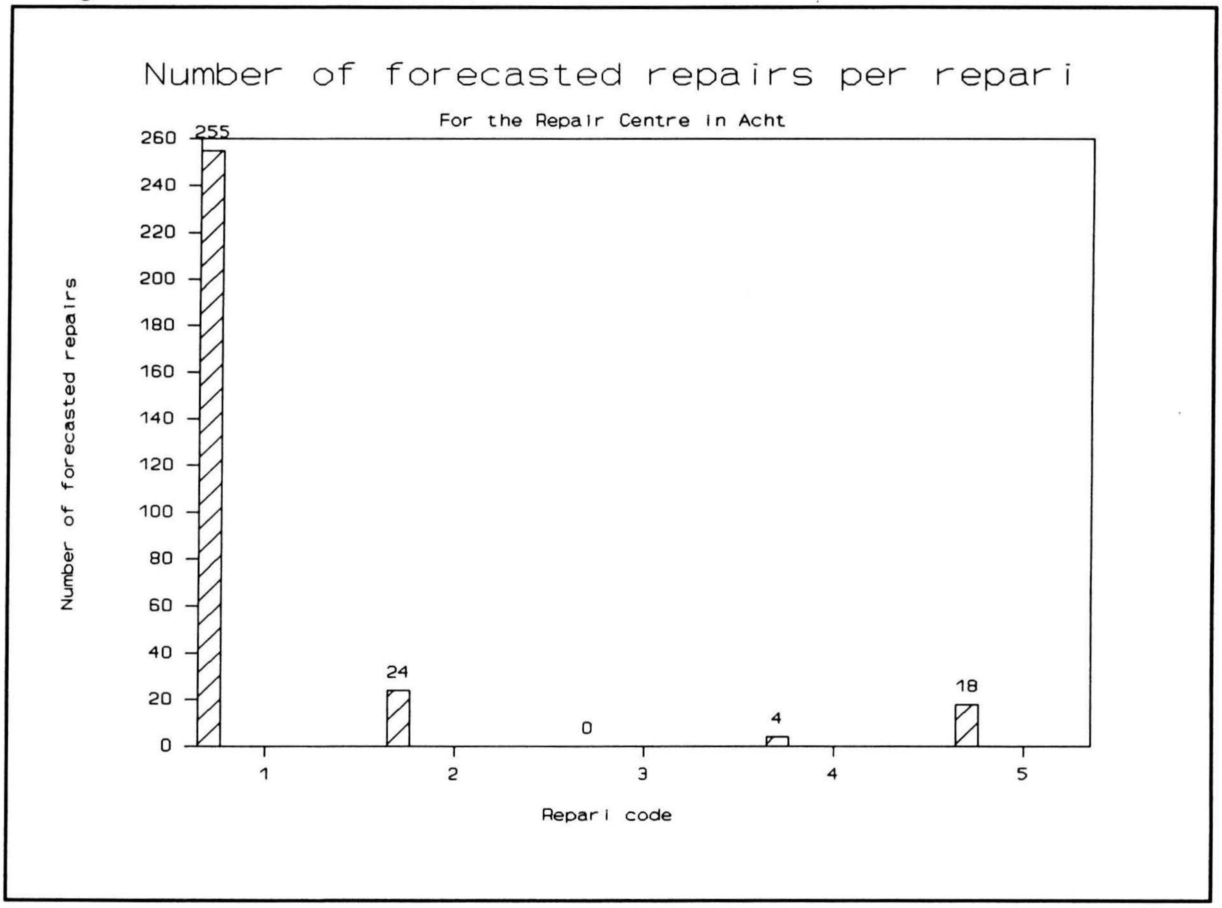
- The number of repairables per Repair Centre, divided per repari code is depicted in figure 5.



- The number of forecasted repairs per Repair Centre is depicted in figure 6.



- The number of forecasted repairs for the Repair Centre Electron Optics per repari, is depicted in figure 7.

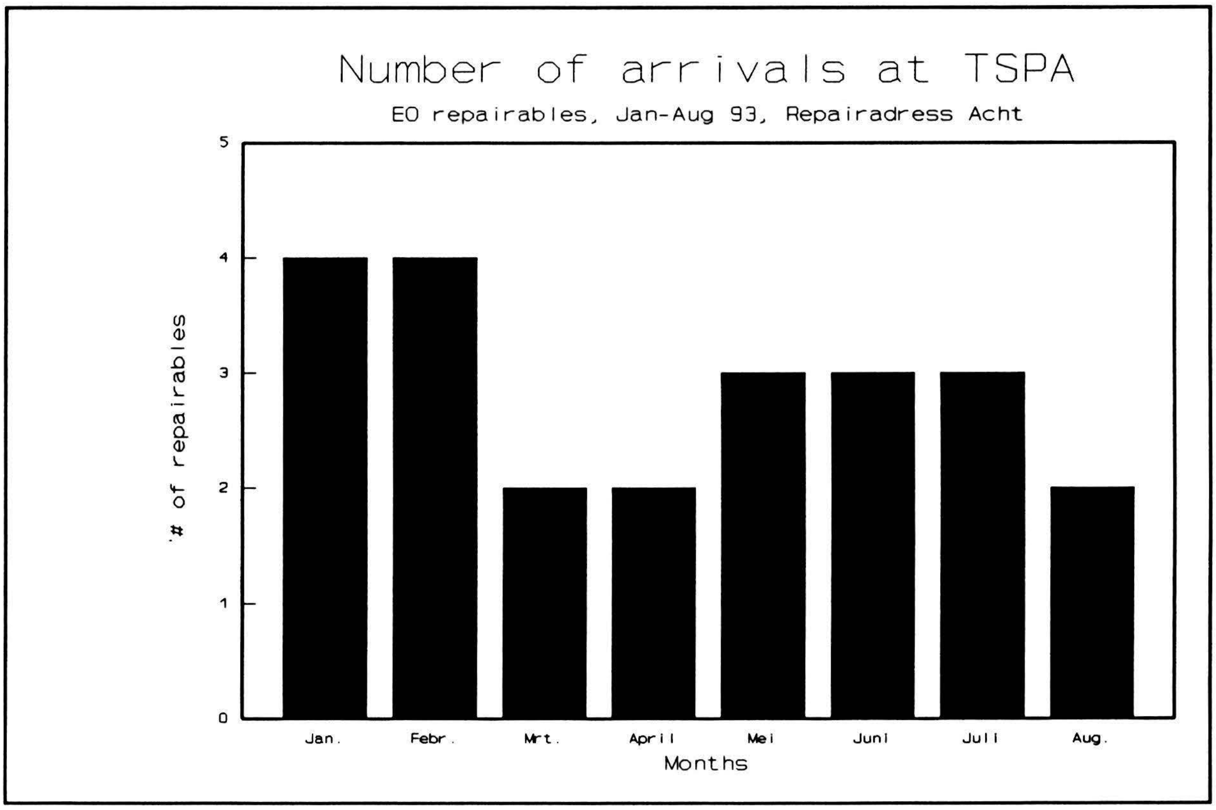


Appendix 14: Process characteristics of EO repairables

Some aspects concerning the flow of EO repairables are mentioned in this appendix.

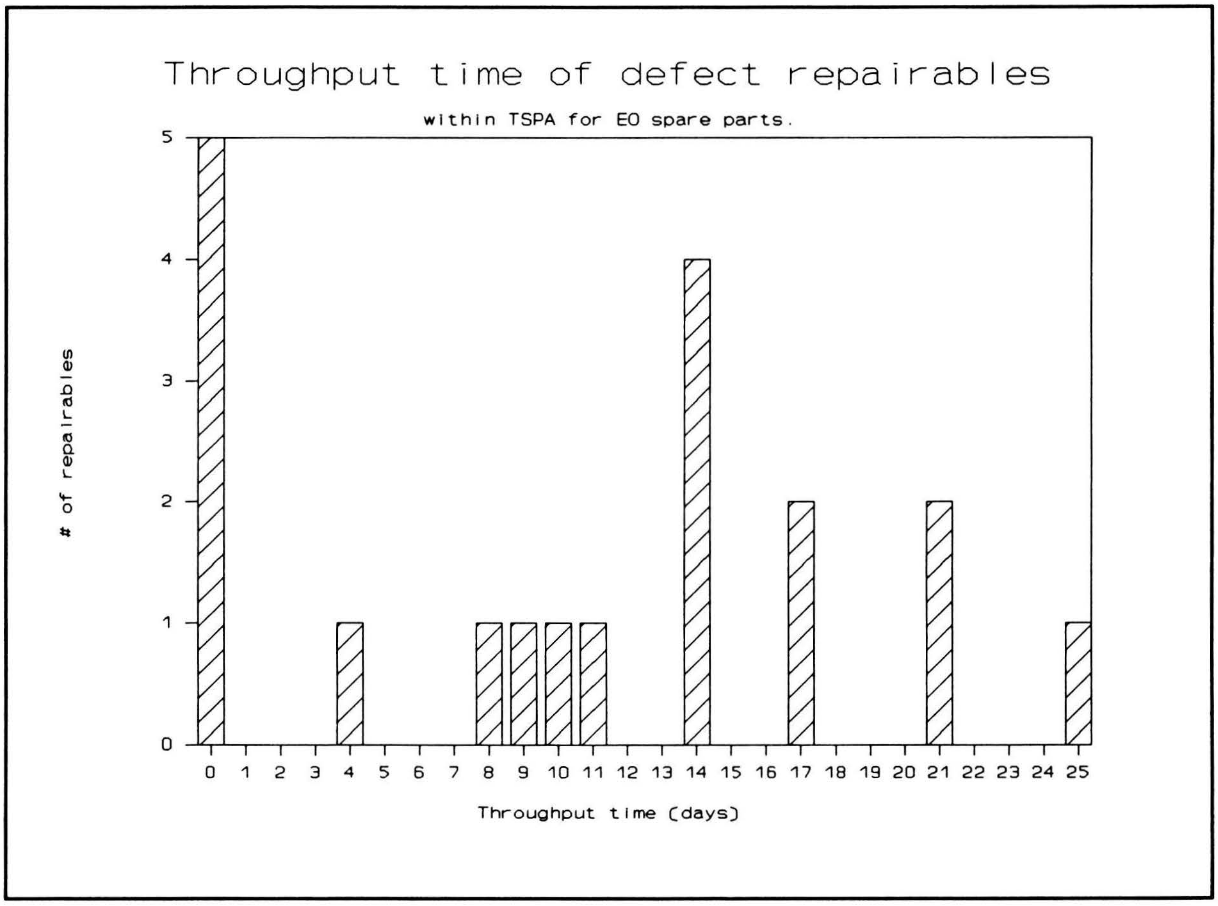
- Number of arrivals at TSPA (Dutch NSO for several OC's)

The total number of arrivals of defective repairables in the period January- August 1993 is 33. It is impossible to do statements about the frequency distribution of a single part. For 23 of the defective repairables the repair address is Repair Centre Acht.



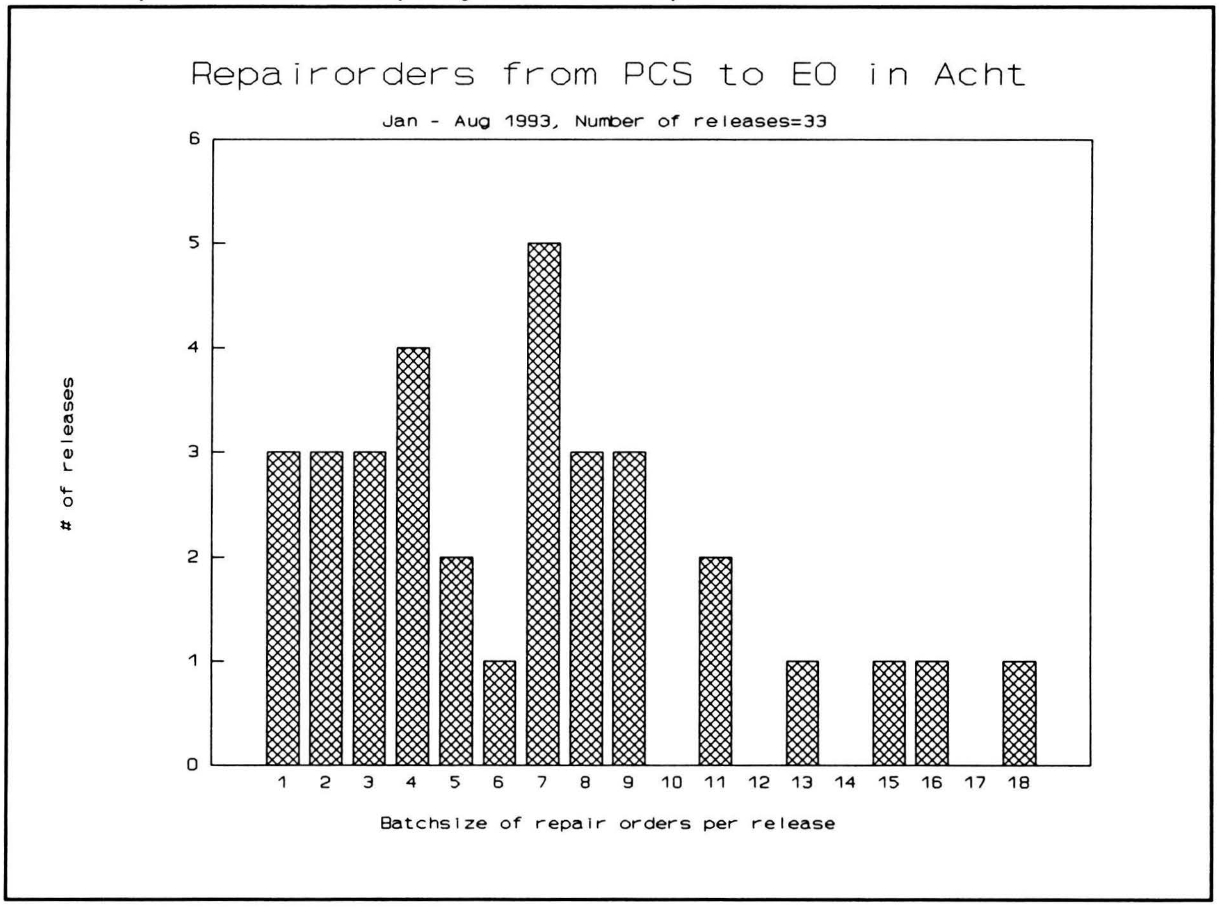
Remarks: Average number of arrivals per month, is three.

- Throughput time of defect repairables within TSPA



Remarks: The average throughput time is ten days
The deviation is eight days

□ The repair order release frequency from PCS to Repair Centre in Acht



Remarks: The average number of repair orders, per repair release, is seven.
The deviation is four repair orders.

Appendix 15: The delivery performance of the EO Repair Centres

The delivery performance of seven Repair Centres (repairing EO-repairables) is measured over the period June 1992 until June 1993. The delivery performance is defined as the percentage of the number of repairs, repaired within the agreed repair leadtime.

Repair Centre (1)	Number of repairs	Delivery Performance (%)
ICV Electr.	1	0
Haefely Basel	3	0
Leybold Woerden	9	100
De Jong B.V.	5	80
AXR Almelo (2)	271	58
EO Acht	331	53
Balzers Maarsen	11	73
Total	631	56

(1) The information about the delivery performance of the repair shop of the OC Power Systems in Wavre is not available at PCS.
(2) Not all mentioned repairs are repairs of EO repairables.

Appendix 16: Goods, information and invoice flow, and logistic organization

For the basic structure with the lowest logistic costs, NSO-Almelo, the goods, information and the invoice flow are shown in table 16.1. Only the activities related to the return flow are described.

Table 16.1: Goods, information and invoice flow.

Goods flow	Information flow	Invoice flow
	1. NSO requests PCS for a repair authorization number.	
2. NSO ships the defective HT generator to Philips Almelo.		3. NSO sends a charged invoice to PCS.
	4. Philips Almelo sends an acknowledgement document to PCS after receipt of the defective part.	5. PCS sends a credit note to the NSO
	6. PCS sends a repair order to EO in Acht.	
	7. EO sends the repair order and a job sheet to Philips Almelo.	
8. Philips Almelo sends the repaired part for test to EO in Acht.	9. Philips Almelo sends an uncharged invoice with the shipment as shipping document.	10. Philips Almelo sends a charged invoice to EO
11. EO sends the tested part to PCS.	12. EO sends an uncharged invoice with the shipment as shipping document.	13. EO sends a charged invoice to PCS

Logistic Organization

The service department of the OC EO has the total responsibility about the whole chain. Some parts of the responsibility are delegated to other entities, see table 16.2.

Table 16.2: Responsibilities.

Responsible entity	Responsible for
NSO	the shipment of the defective parts to Philips Almelo within the agreed time.
Philips Almelo (Repair Centre)	sends an acknowledgement to PCS that the defective part has arrived.
	repair the HT generator after a repair order is received from Supply Centre EO in Acht.
	sends the repaired parts within the agreed time to Supply Centre EO in Acht.
Supply Centre EO	the control of the return process from the NSO to Philips Almelo; when NSO's do not ship the defective parts within the agreed time, Supply Centre EO has to contact the NSO's.
	send a repair order to Almelo.
	the control of the repair process; when Almelo does not repair the part within the agreed time, Supply Centre EO has to contact Philips Almelo.
	test the HT generator after repair.
	the control of the test process.
	the return shipment from Supply Centre EO to PCS.
PCS	the stocking and despatch of new/repaired parts.
	control of the stock of new/repaired parts.
	release repair orders; send a repair order to EO
	release replenishment orders
	send an weekly overview to Supply Centre EO of the parts still to be received from the NSO's. (*)

(*) With the help of this overview, it is possible for Supply Centre EO to trace the outstanding parts.