MASTER

COMMIT : the theory and practice of consolidated repairable item management in the NATO environment

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Common Item Material Management

NAMSA

COMMIT

"The theory and practice of consolidated Repairable Item Management in the NATO environment"

NAMSA

Let's keep nations together

NATO MAINTENANCE AND SUPPLY AGENCY
CAPELLEN, G.D. OF LUXEMBOURG

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Thesis Report
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Preface

This report has been written in order to complete my studies at the Eindhoven University of Technology, and to comply with the requirement of performing a thesis..

I would like to take this opportunity to thank all the people from NAMSA, the participating Armed Forces and the University, who have helped me during the performance of this project. There are too many people to name them all, but three people from NAMSA and two from the University, I would like to mention by name.

Firstly Nico Oorebeek and Jo Kneepkens, who made it possible for me to obtain this useful experience. I would also like to thank Günter Steiper, he was always ready to oblige me, even when I asked only for yet another "5 minutes".

From the University, I like to thank my two co-ordinators, Harry Martin and Cees Kokke for their advise and co-operation.

Finally I would like to say that I am grateful to have had the opportunity to finish my study in an organisation such as NAMSA. I realise that the experience to work in an organisation where 15 nationalities co-operate, is very special.

Claudia Paro
August 1997

Abstract

This report describes a study concerning the possibility of consolidating the management of repairable items between Armed Forces. Two models are introduced. First a model to support the decision as to whether an item must be considered as a repairable or as a consumable item. A second model, to calculate the number of items needed in a repair loop to achieve a certain service level is described. Both models are applied and evaluated.

Summary

This study is performed in the NATO Maintenance and Supply Agency (NAMSA). NAMSA is the executive arm of the NATO Maintenance and Supply Organisation which was created by a North Atlantic Council decision in 1958. NAMSA is located at Capellen , in the Grand Duchy of Luxembourg.

NAMSA has proposed a way to reach one common framework for Co-operative Logistics. This framework is constructed from three modules namely:

1. The Stock Holding and Asset Requirements Exchange (SHARE)
2. The Common Item Material Management System (COMMIT)
3. Provisioning File for Items (PROFIT)

This study is performed in connection to the feasibility study of COMMIT.

COMMIT is a concept that permits the Armed Forces to jointly manage NATO common items. A common item is defined as an item that is used, under the same NATO Stock Number (NSN), by two or more Armed Forces. Within NATO there are approximately 2,750,000 common items. The concept of COMMIT is a *"virtual stock"* approach.

A feasibility study had to be performed to provide the necessary information to allow the Board of Directors (BoD) to take a decision on whether or not to approve the implementation of the COMMIT project.

The collection of data to perform the feasibility study was already in progress. Data concerning the logistic parameters of the 5,120 common items between the armies of Belgium, Denmark, Germany, Netherlands and Norway were collected from each army. From that point the preliminary assignment was formulated as:

> *"Evaluate the demand data, by making calculation of consolidated demands for all users (5 armies) by using different logistics scenarios. Also, if time was available, an evaluation of the EDP requirements should be performed."*

Simply explained, the final situation of COMMIT, as currently proposed, will be one overall (global) stock control system combined within each Armed Force as well as their individual systems. The individual systems have to be managed by the Armed Forces themselves. The global system will be managed by NAMSA.

In a first stage, only consumable items should have been considered in the study. But during the initial analyses it became obvious that many questions still exist. From these questions it is concluded that repairable items must be considered in the feasibility study. This is because of the dependency between the consumable and repairable items. Considering the lowest level on the Bill of Material, a repairable item is an assembly of consumable items.

After the first analyses of the study sample comprising of the 5,120 common NSN's between the five participating Armed Forces, it seemed that 60% of the global stock value represents the

NSN's which are repairable in at least one Armed Force. The number of items represents only around 20% of the 5,120 NSN's in the study sample.

The dependency between the consumable items and the repairable items in combination with the high stock value for the repairable items resulted in the following assignment:

> *"Develop and evaluate models which support the decision on whether an item will be considered repairable or consumable. and, if the item is considered as repairable, in which situations is consolidation of repairable items advisable?"*

Concerning these assignments, two models were developed. One model to support the decision as to whether an item must be considered consumable or repairable, and a second model to calculate the number of items which are needed in a repairable item loop to achieve a certain service level. Both models are evaluated by application of a small sample of items.

Decision model: Repairable or not

The model exists out of three steps:

1. Evaluation of the current global stock level
2. Comparison of repair and procurement parameters
3. A cost analyses

In the first step the Out of Stock Period (OSP) is calculated if the item is considered as a consumable. This OSP is compared to the remaining expected life time of the system. The remaining life time of a system is almost never known and difficult to estimate. For this reason limits are set in connection with policies used in NAMSA. If the global OSP is longer than 10 years, the item will be considered as a CI. If the OSP period is between 5 and 10 years, the item will temporarily be considered as a CI. Items with a OSP less than 5 years must be researched in more detail before a decision can be taken.

The second step in the model, procurement lead times (PLT), average repair times (ART), procurement prices (PP) and average repair prices (ARP) are related to each other. This step is included in the decision model because it often happens that a long PLT results in considering an item repairable, even if the ARP was several times higher than the PP.

The last step in the model is a cost comparison. All costs which arise during the life time of an item must be considered. Two cost comparisons are discussed. One simple model where the difference in costs, if the item should be repairable or consumable, is expressed in the demand (or number of replacements). The second comparison is based on the Life Cycle Cost Analysis. This is a systematic analytical process of evaluation whereby various alternative courses of action are considered, with the objective of choosing the best solution. The aim of this discussion is to provide insight into which costs categories increase or decrease per item, using the several stock management systems. Five stock management systems are considered; consumable consolidated, repairable individual self, repairable individual contractor, repairable consolidated self and repairable consolidated contractor.

The turnaround model: Consolidate repairable items or not

A second model is discussed, this is to calculate the number of turnaround items, needed in a repair loop to achieve a certain service level. This model is based on a combination of the classical queuing theory and a Markov routing. The repairable loop is modelled as a closed system with two multi-server stations and a fixed number of items in the system. The multi-server stations are one *"usage station"* which models the usage process and one *"repair station"* which models the repair process. The quantity of items in use is equal to the number of *"usage servers"*. The quantity of items that can be repaired the same time is equal to the number of *"repair servers"*. The total number of items needed to achieve a certain service level is calculated for each individual Armed Force and for one consolidated situation. The sum of all items needed in the individual Armed Forces is compared to the consolidated situation. If the number of items needed in the consolidated repair loop is less than the sum of the individual repair loops, for an equal service level, consolidation makes sense.

Evaluation of the models

From the first study sample, a selection is made to apply and evaluate the models. This data collection is limited to armies of BE, GY and NE. Twenty four items are selected from which five items are currently considered repairable in the three armies. The remaining 19 items are miscellaneous repairable and consumable items in the armies.

Decision model: Repairable or Consumable

Step 1: Evaluation of the current global stock level
After applying the first step of the decision model, 8 NSN, out of the 24 NSN's, can be considered as consumable because of their enormous global stock level. Three NSN's can be considered as temporary consumable, also because their global stock levels, which are sufficient to cover five to ten year the average demand.

The first step in this decision model is an obvious but useful step. It seemed that, based on the serviceable stock position, more than 30 % of the items can be considered as consumable in a consolidated situation.

Step 2: Comparison of repair and procurement parameters
Within this study, this step cannot be performed as it should be. Out of the remaining 13 items, only for two items could a decision be taken. Namely one repairable and one consumable. And even for these NSN's estimations are done for certain values. For six items it was decided to exclude these from further research, because of unreliable data. The result of this step did not meet the expectations. Several aspects are the cause, namely:

- If an NSN is considered as consumable item in one of the Armed Forces , no repair parameters are available in that Armed Force in case the item should become repairable. It was planned to use the values from the Armed Forces where the NSN was already repairable. This was not done, as the differences in these values between the Armed Forces, for NSN's where more Armed Forces have data available for certain (repairable) NSN's, were too important, and the difference was too big. Estimation from these values should not result in valid values.

- Much of the required data is missing. If an NSN is considered as repairable, all four parameters are often not provided. Besides this, average repair prices and time equal to zero occur.
- It is only allowed to compare parameters if their meaning is identically equal. As long it is not known what is included in the repair prices and times, this step may not be done.
- The type of repair must be equal. One cause of the big differences in the values of the repair parameters could be that the type of repair is not equal on the national level.

As long as the provided data is not reliable, it is not sure that the repair tasks are equal. This combined with the point that the exact meaning of the parameters are not known, this step is not useful. This step could only be useful to show the relations between procurement and repair times and prices. Even so, if all parameters are known, this step can be used to show extreme situations.

Step 3: Cost analyses.
As was expected, only a simple cost comparison could be performed. Without information about repair facilities, no decision can be made. The enormous difference in the various parameters is again clearly out of this step.

Turnaround model: Consolidate repairable items or not

Only for one NSN was it decided to consider it a repairable. For five items, no decision could be made in step 3 of the decision model. These remaining 6 NSN's are used to evaluate the turnaround model.

For only one NSN out of these 6, could the turnaround model be applied. This result does not meet the expectations because of several reasons, namely:

- Many parameters which are needed to apply the model can often not be provided. The parameter "number of items in use"' is the most difficult parameter to provide.
- In all cases where sufficient parameters were provided it occurred that no satisfactory results were obtained. For example no replacements took place over the researched period. Or the repair times were so long that only temporary improvement of the service rate could be achieved; that means in the steady state situation, an infinite number of turnaround items is needed.
- It was assumed that the number of repair servers is equal to the number of items in repair as long as items are waiting for repair. This seems not to be correct. Often, items are waiting for repair but no items are in repair.
- Even if the probabilities were calculated with the use of the re-current relation, the limits of Excel v5.0 were reached. Because it took the Armed Forces more time to collect the data than was expected, there was no time left to do the calculation in another way.

Notwithstanding that the model could not be applied with practical data, the following facts became obvious:

- A satisfactory service rate can only be achieved if the average number of failed items per time unit is about (equal), or less than, the maximum number of items that can be repaired in a that time unit ($\frac{m(1-s)}{MTTR} \leq \frac{n}{ART}$

  where: m = number of items in use
  s = scrap rate;
  n = number repair servers;
  $MTTR$ = Mean Time To Replacement
  ART = Average Repair Time).
- If $\frac{m(1-s)}{MTTR}$ is much smaller than $\frac{n}{ART}$, the service level will increase enormous by adding one item in the turnaround loop. The larger the difference in this direction is, the more the service level will increase by adding one item.
- The closer $\frac{m(1-s)}{MTTR}$ is to $\frac{n}{ART}$, the more impact a consolidation of the repair loops has.

If the correct data is available, the turnaround model can be used to research whether consolidation makes sense or not. But the correct data is difficult to obtain. To receive exact data, detailed information about the operational concepts, the maintenance concepts, the background of the current method of managing the repairable item etc. must be known. To clarify this, each item must be researched separately in detail, and within each Armed Force, and also the repair facilities must be considered. Thus the general conclusion is that the turnaround model is theoretical justified but practically difficult to apply.

Conclusions and Recommendations

In general one can say that the application of the developed models need such detailed data that in this stage of the COMMIT study no reliable figure on possible savings can be achieved. Even an estimation is not done opportune because the provided data was too divergent. The developed models can well be used to provide insight into which parameters do influence the decisions, the values of the impact can be seen as well.

Subsequent to this study, a more to the individual Armed Forces adopted study is recommended. Minimal requirements for the Armed Forces concerning the provisioning of data must be set. Only under their conditions, the individual Armed Forces may fruitfully participate in COMMIT.

A second recommendation is a comprehensive simulation study to research the influence of several parameters. A large number of parameters which are not (exactly) known, do influence the decision whether consolidation makes sense or not. For example the demand distribution or the transport times arising from "borrow activities" in a consolidated situation.

Contents

Chapter 1

Introduction

1.1 Background

This report is written in connection with the dissertation of Claudia Paro, towards a Master of Science Degree in Industrial Engineering, faculty of Technology Management, Technical University of Eindhoven, the Netherlands. The study is performed during practical work experience at the NATO Maintenance and Supply Agency (NAMSA), located at Capellen, in the Grand Duchy of Luxembourg, and has been completed during the period December ‘96 to July ‘97.

1.2 Motivation for this research

NAMSA expects that a lot of advantages can be utilised in the member countries of the NATO, by a joint management of common items. At this time, each individual member country of NATO, manages their own stock. This individual stock management leads to a situation where every Armed Force performs similar work and all the Armed Forces have to maintain their own buffer stock.

A proposal to reach a joint management of the common items is introduced as the Common Item Material Management (COMMIT) project. At this point, it must be examined whether the expected advantages are really substantiated. The target of this research is to draw valid conclusions about these possible advantages.

COMMIT is a sub-project for a common framework for Co-operative logistics. After a short introduction about the organisation, this framework will be discussed in Chapter 3. Following this chapter, Chapter 4, a detailed description of the first concept of COMMIT will be given.

1.3 Preliminary description of assignment

The preliminary assignment at the start of the dissertation period was to perform a feasibility study of the COMMIT project. Collection of data from five of the participating countries, Belgium (BE), Germany (GY), Denmark (DK), Netherlands (NE) and Norway (NO) was already in progress. The preliminary assignment in detail states:

> *"Evaluate the demand data, by making calculation of consolidated demands for all users (5 armies) by using different logistics scenarios. Also, if time was available, an evaluation of the EDP requirements should be performed."*

1.4 Framework of the study

The study can globally be divided into five phases. These phases are derived from the guidelines advocated by Ackoff (1981). He suggested a structured planning method that can be used for projects which are conducted in a complex environment.

Phase 1: "Formulating the mess"
This phase will be discussed in Chapter 2. The position of NAMSA within NATO and the internal structure of NAMSA are explained. The mission of NAMSA will be discussed as well. This chapter will finish with an explanation of the setting of COMMIT within the total common framework of, the NATO Co-operative Logistics Services. The aim of this chapter is mainly to inform the people who are not familiar with the organisation.

Chapter 3 contains a more detailed description of COMMIT. In this chapter three sub-problems within COMMIT came up. One of these sub-problems is, in deliberation with the project supervisors, chosen for further research.

A prediction of the future if no research will be performed, is not applicable for two reasons;

1. It is virtually impossible to get information about the exact policies which govern the individual Armed Forces.

2. If this research is not carried out, each Armed Force will run its own system. As stated before, how the Armed Forces control their items is difficult to discover, so it is even more difficult to estimate what the future situation for the individual Armed Forces will be.

The sub-problem chosen in deliberation with the project supervisors, is the question concerning the repairable items. The motivation for this choice is described in Chapter 3. The remaining phases will only be followed for the repairable items.

Phase 2: "Ends planning"
The second part of Chapter 4 will focus on the required end situation of this research. At the end of Chapter 4, the final description of the assignment, the goals, the research questions and the scope of the research will be made clear.

Phase 3: "Means planning"
In Chapters 5 and 6 a model will be discussed, which could be used to achieve the goals of the research project.

Phase 4: "Resource planning"
Chapters 5 and 6 describe which resources are needed to apply the models.

Phase 5: "Design of implementation and control"
In Chapter 7 a first attempt will be made to apply the models. The models are applied for a selected number of items. However because of a limited set of data, general conclusions cannot be drawn. The application presented here serves only as a demonstration of the methods developed in the previous chapters.

Chapter 2

Introduction of NATO Maintenance and Supply Agency (NAMSA)

2.1 Introduction

NAMSA is the executive arm of the NATO Maintenance and Supply Organisation (NAMSO) which was created by a North Atlantic Council decision in 1958. NAMSA is a non-profit making agency with an international outlook, motivated by the following simple philosophy:

> *"By providing centralised maintenance and supply management, it is possible to consolidate the requirements of a number of countries, to hold a central stock of spare parts and to make bulk procurements, the result being that maintenance services and parts are furnished at less cost and more quickly than when individual nations make their own arrangements, sometimes in competition with one another (NAMSO Charter 1988)".*

This chapter contains a general introduction to NAMSA, its situations in the NATO structure, an explanation of the organisational structure and the mission of NAMSA. Also in this chapter, the NATO Co-operative Logistics Services are introduced. This is the division where the study is performed.

2.2 The organisation

NAMSA was established to serve the NATO nations, its policies being determined by the NAMSO Board of Directors (BoD) - composed of among others, representatives of the organisation's 15 member countries (all NATO nations except Iceland) - which ensures that individual national interests are taken into account. A schema of NAMSA's position within NATO is shown in figure 2.1

The Secretary General of NATO as well as the Supreme Allied Commander Europe (SACEUR) are represented in the BoD who is directly responsible to the NATO council. The BoD's role is to define the policy to be followed by the Agency, to approve the annual budgets and personnel establishments, and to control the Agency's performance. The BoD is assisted by two permanent committees, the Logistics Committee and the Finance and Administration Committee, both of which give technical advice before the BoD makes the final decision. There are also Weapons Systems Partnership Committees (WSPC's). The role of a WSPC is to define the particular policy to be followed for it's own weapon system which is used in several NATO member countries and is logistically supported by NAMSA. The BoD retains the right to approve such policy decisions.

NAMSA's real "customers" are the national material commands of the NATO Armies, Air Forces, Navies as well as Supreme Headquarters Allied Powers Europe (SHAPE). SHAPE is an operational command.

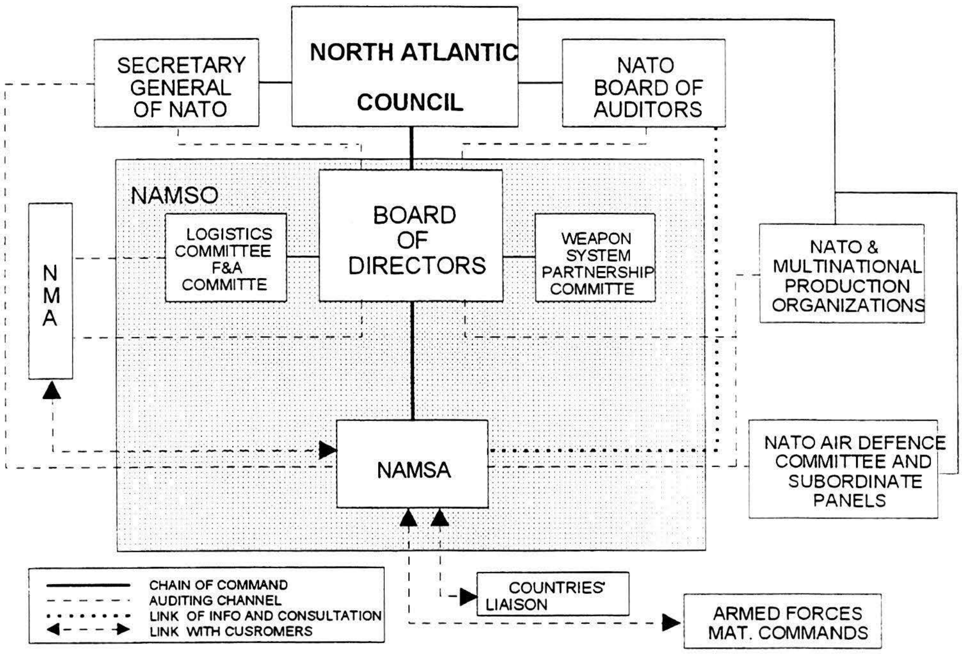


Figure 2.1: Main organisational structure of NATO (Mönch and Sadlowski 1990)

2.3 The internal organisational structure

NAMSA's main facility and the majority of its work-force, around 950, are located at Capellen in the Grand Duchy of Luxembourg. A second facility, Southern Depot, is located at Taranto, Italy. A third facility, the HAWK Logistics Management office, supporting solely the HAWK Air Defence Weapons System, is located near Paris, France.

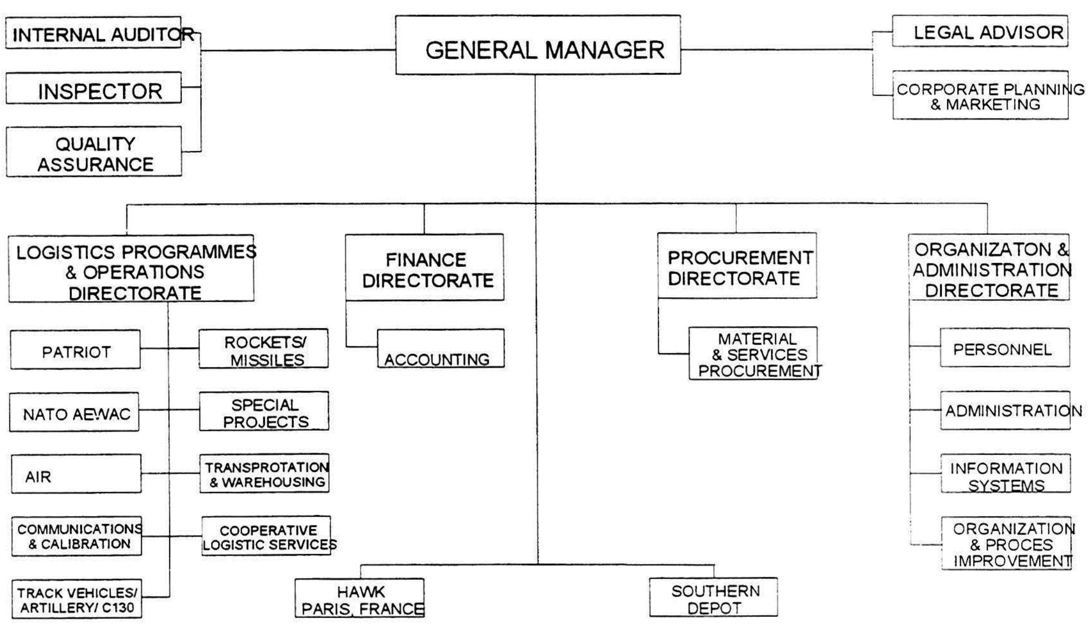


Figure 2.2: Organisation structure NAMSA (Mönch and Sadlowski 1990).

NAMSA's Organisational structure shows four directorates and their divisions or programs. The General Manager controls, and is directly responsible to the BoD, for all Agency elements and their operation.

The four directorates are:

- Logistic Programmes and Operations.
  This is the largest directorate and is responsible for developing the concept and policy for NAMSA's support functions and to execute all supply and service support tasks. The directorate is responsible for different Program Offices which provide the support for specific programs or Weapon System Partnerships (e.g.: Air Defence Program, Rocket/Missile Programme, Patriot Missile Program, the Warehousing and Transportation division, etc.). COMMIT is a project in the Co-operative Logistic Services program, which will be described in paragraph 2.5.
- Finance.
  Provides the financial management support to NAMSA's programmes.
- Procurement.
  This directorate handles the procurement of material and services ; such as identifying more competitive sources and establishing reliable source files.
- Organisation and Administration.
  Four divisions are identified. These are Administration Division (reproduction, communications, security, etc.), Personnel division (recruitment, personnel administration, etc.), Manpower and Organisation & Management division (number-, grade, and work-load for personnel) and EDP Support division.

2.4 The mission

NAMSA's mission as defined in the NAMSO Charter is:

> *"providing logistic services, in peacetime as well as in wartime, in support of weapon and equipment systems held in common by NATO nations, the aim being to promote material readiness, to improve the efficiency of logistics operations and to effect substantial savings through consolidation of procurement".*

To accomplish this mission, NAMSA exercises it's responsibilities in the areas of supply, maintenance, calibration, procurement, transportation, technical support, engineering services and configuration management for some 30 weapon and equipment systems. Other activities include codification/identification services and arranging contracts for the disposal of all types of ammunition.

2.5 The NATO Co-operative Logistic Services

The provision of logistics within NATO has evolved over the years from a national, to a collective responsibility. Until now, there is no unique NATO logistics support system which is composed of national and NATO international elements fitting together, logically, into one common framework.

To reach one common framework, NAMSA has proposed a strategy for Co-operative Logistics. NATO Co-operative Logistics is a strategy to implement logistics support concepts, measures and tools that will benefit the whole of NATO. This strategy seeks to gradually implement a NATO architecture plan. This plan will permit Armed Forces to be conceptually, procedurally and electronically linked together. This will result in the possibility to jointly manage common logistics requirements. These common logistics requirements may be in the field of material management, training and other logistics support needs.

The framework of Co-operative Logistics is constructed from three modules: SHARE, COMMIT and PROFIT.

2.5.1 Stock Holding and Asset Requirements Exchange (SHARE)

SHARE is a concept that permits the Armed Forces to directly work together in the field of material management (Zweerts 1995). It is possible to report material for availability and exchange material assets. In this system, Armed Forces become buyers and sellers amongst each other.

The SHARE service started official operations in July 1996. Until now, after one year, the SHARE service has 14 subscribers. The total transaction value during this year is over one million US dollar.

2.5.2 Common Item Material Management System (COMMIT)

COMMIT is a concept that permits the Armed Forces to jointly manage NATO common items. A common item is defined as an item that is used, under the same NATO Stock Number, by two or more Armed Forces. Within NATO there are approximately 2,750,000 common items. The concept of COMMIT is the "virtual stock" approach. COMMIT was presented to the BoD in July 1996. COMMIT will be discussed in detail in Chapter 4.

2.5.3 Provisioning File for Items (PROFIT)

PROFIT aims to establish a unique international provisioning source file for NATO common items. This concept gives the Armed Forces the possibility to improve provisioning of their items on an individual basis. PROFIT aims to permit NAMSA to improve acquisition of items for which requirements have been consolidated.

Chapter 3

Common Item Material Management System

3.1 Introduction

As already mentioned in Chapter 2, COMMIT permits Armed Forces to jointly manage NATO common items. Instead of adding a hierarchical level above the national depots, the aim will be visibility of the national stock positions. The participating Armed Forces will have visibility of each others stock-levels. A so called *"virtual stock approach"* as shown in figure 4.1 In this chapter the background of COMMIT will be discussed in detail.

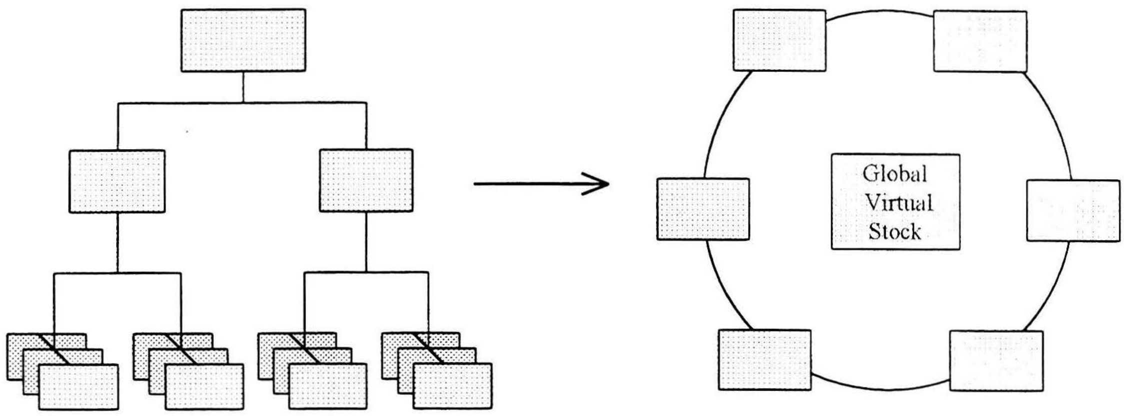


Figure 3.1: The virtual stock approach.

At this point the following major advantages are seen for the participating NATO members (Oorebeek January 1996):

- reduction of the risk of excess
- higher service level at lower cost
- reduction of costs
- better supplier conditions (price, delay, quality)
- the establishment of a joint virtual wholesale level stock
- reduction of national stock holdings
- reduced supply management labour in the countries
- reduced procurement labour in country

3.2 Explanation of the system

The way of processing repairable items (RI's) is different than processing consumable items (CI's). In first stage only the consumable items will be considered in COMMIT.

The proposal for COMMIT, introduced by NAMSA, is described in this paragraph.

Simply explained, the final situation, as currently proposed, will be two stock systems in one. One global system, and one individual system for each Armed Force. The individual system has to be managed by the Armed Forces themselves. The global system will be managed by NAMSA.

The global safety stock and the global re-order point will be calculated by NAMSA. When an individual country is below its re-order point but the global re-order point is not yet reached, an order shall take place and material shall be shipped from the Armed Force where the stock situation is still comfortable. When the global stock re-order point is reached, a decision for stock replenishment is required.

Before COMMIT is operational, two phases will be passed. The first phase will consist of the redistribution and reduction of stocks. This concerns the individual stocks as well as the global stocks. The second phase, will be the implementation of the global and the individual control systems.

The global and the local (individual) control systems are explained below. Both descriptions and flow diagrams are derived from the proposal made by NAMSA.

3.2.1 The global system

The final functionality of the global control system, proposed by NAMSA, is shown in figure 3.2 and appendix II. The diagram shows actions to be taken at time of inventory review. When speaking of review periods and re-order points, one could assume that the inventory control system will follow a Statistical Inventory Control (SIC) approach (Silver and Peterson 1985). However this assumption is not made. If for example, the spares are bought for the entire life time of a weapon system, one time purchase (Nevels 1991), the review period (R) will be infinite, or the re-order point will be equal to zero. In cases where an inventory system uses continuous review, the review period will be equal to zero.

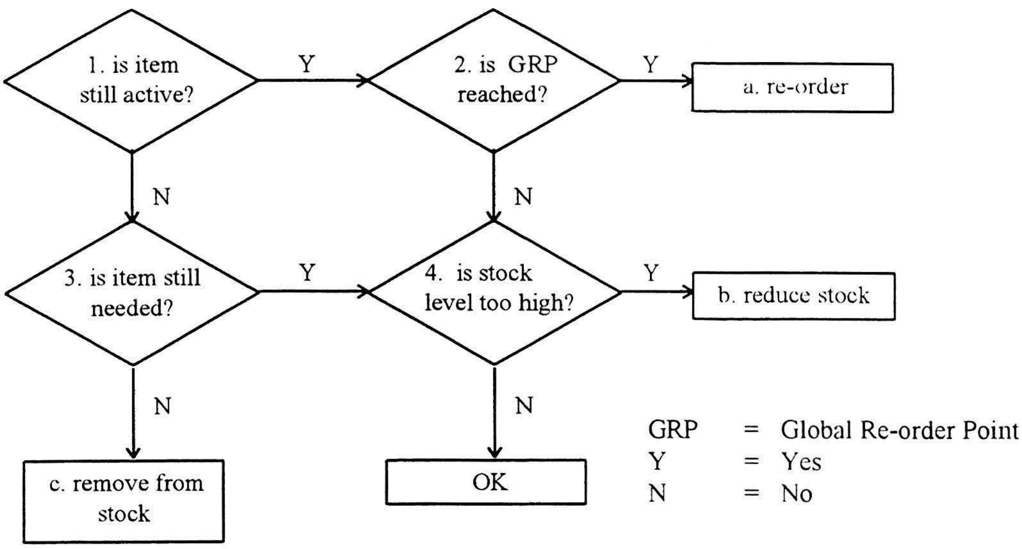


Figure 3.2: Working of global system

First, a check is performed to see if the particular item is still active in the global system. In other words, has there been a demand from at least one of the participating Armed Forces during the last (fixed) period. This period should be fixed and can be chosen from within the global system. In this report an item is defined as an active item if there has been at least one demand in the last 2 years. If the item is still active, a check, to determine if the global re-order point (GRP) is reached, is performed. If the GRP is not reached, a check is performed to see if the stock level is too high. If this is the case, the stock level has to be reduced, otherwise no action will be taken at this review period. If the global re-order point is reached, this item has to be ordered. Then a classic stock control system is applied.

In the case where no demand has occurred during the last two years, there must be a check to see if this item is still in use, either as an independent item or as a part of a technical system / sub-assembly. If the answer is no, it makes no sense to keep this item in stock any longer. If the answer is yes this must be checked to see if the present stock level is too high. In cases where the stock level is too high, we have a global surplus stock.

The actions that could be taken are: 're-order the item', 'reduce stock level' or 'remove from stock'.

3.2.2 The local (Armed Forces) system

The final functionality of the individual systems, proposed by NAMSA, is shown in figure 3.2 and appendix II. Similar to the global system, it is not necessary that the local inventory is controlled by a statistical control system (see *global system* §3.2.1.).

The first step on a 'general review point' is to check if an item is still active (nationally). If the item is still active then this will be checked if the local re-order point (LRP) is reached. In case this point is reached, the item must be ordered. There are two possibilities to obtain the item. The first option is to wait for delivery because the global re-order point is/was reached and items are in the incoming pipeline or are in the process to be ordered. If this waiting-time is acceptable then no action will be taken. But if the global re-order point is not yet reached or if there is an urgent need, a search of the other participating Armed Forces is performed to see if one could deliver this item.

In the case where an item is still active and the re-order point is not yet reached then a check is performed to see if the present stock level is still not too high. In practice this will probably not be done very often. But in theory, this should be done because it is possible that the stock level may increase or decrease because the density of usage of the item is changed. If the stock level is satisfactory, no action is required. If the stock level is too high, the stock level has to be reduced.

In cases where the item is inactive (first step 'review point'), a check must be performed to see if the item, or the technical system which uses this item, is still in use. If this is the case a check must be performed to see if the stock position is still reliable. If not, the stock level must be reduced. If the item is no longer used locally, then the item must be taken out of national stock. For example this could be done by selling the items to another Armed Force.

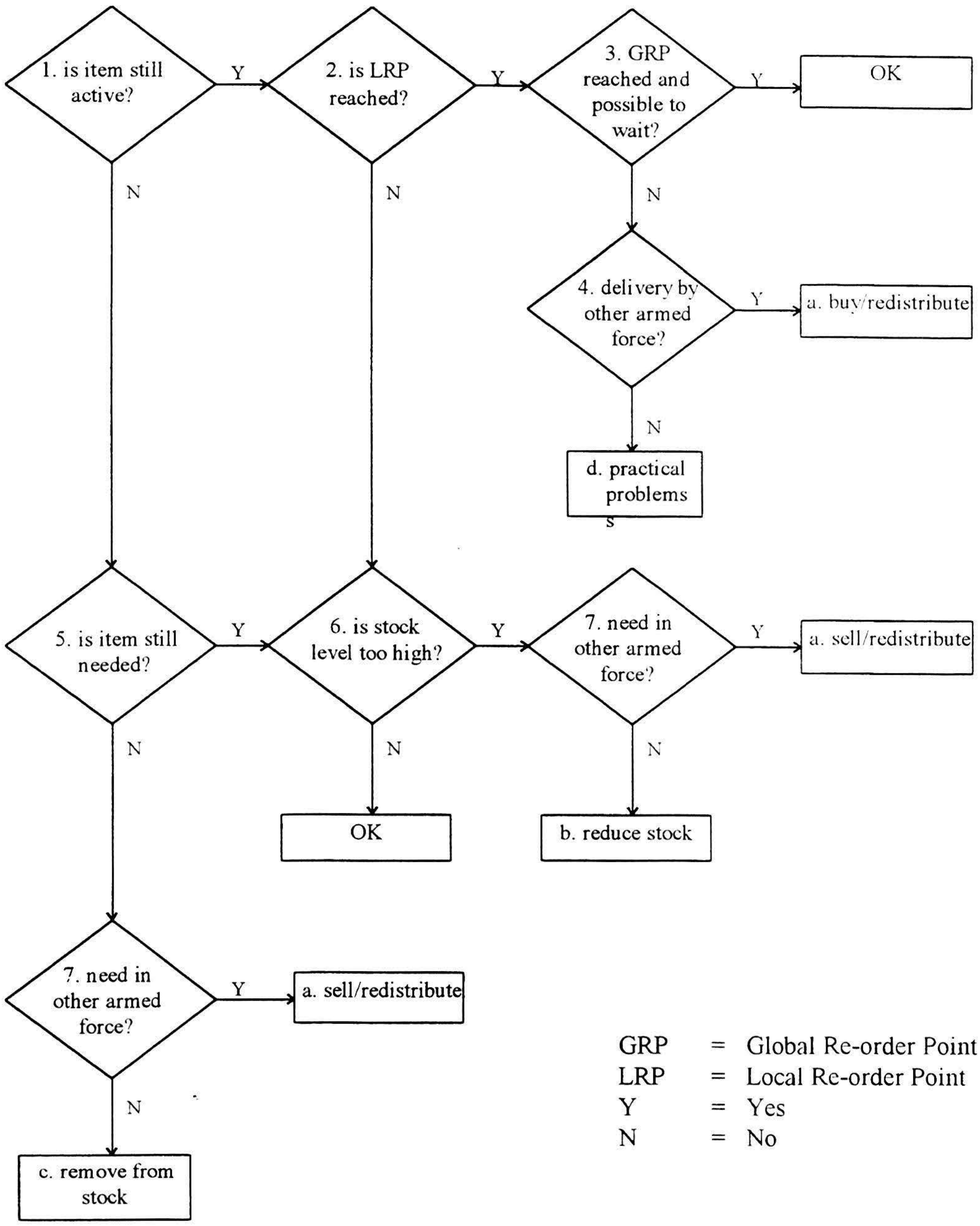


Figure 3.3: Working of local system

3.3 Question marks in the system

To introduce the virtual stock approach takes more than just introducing a new inventory control system. A large number of uncertainties, such as the establishment of stock control policies, are involved with the introduction of such a system. These uncertainties will be discussed by considering each decision and action point (Figure 3.2/3.3 and Appendices I/II) step by step.

3.3.1 Global system (questions/considerations)

Decision points:
(1) Is the item still active? This decision depends on the definition of an active and inactive item. A matter of definition.

(2) Is the global re-order point reached? If a statistical control model is used, the general establishment of the re-order point is the safety stock plus the expected demand during the lead time. But in cases where relatively long lead times are experienced, it may well be that multiple procurement actions for partial quantities are made during the period. In this situation, it is not necessary to add the expected demand during the entire lead-time, however it is enough to add a part of the demand during the lead time. Thus the replenishment policies must be known in order to establish the re-order level. Even the policies for the establishment of the safety stock must be known to establish the re-order level. It is also possible that the model is not based on statistics, but, for example, on planning. In this situation there is no need to calculate a re-order point. Consequently it can be concluded that by establishing a re-order level, the replenishment policy must be known.

(3) Is the item still needed? If this item is a part of a higher assembly, several questions need to be answered, for example:

- What is the dependency between the item and the higher assembly?
- How long is the remaining time that the higher assembly will be used?
- How many of the higher assemblies are currently in use?

(4) Is stock level too high? A decision is again largely dependant on policies as well as the logistic scenario that will be used (see also decision point 2).

Action points:
(a) Re-order. The questions to be answered are:

- Where to order?
- How much to order?
- If the order arrives where to stock it, etc.?

This again depends on the policies, as well as the logistic scenario.

(b) Reduce stock / (c) Remove from stock. The action points (b) and (c) can be combined. In both cases there is surplus stock. Surplus stock could be offered to the non-COMMIT participants NATO wide, through SHARE. The fact is that a COMMIT member must use the SHARE infrastructure, but a SHARE user is not obliged to become a COMMIT participant.

3.3.2 Local system (questions/considerations)

Decision points:
(1) Is the item active? see also *global system* decision point (1) above.

(2) Is local re-order point reached? All local systems are individually managed by the Armed Forces themselves. Questions still to be answered are for example:

- What is the dependency between the local re-order points and the global re-order point?
- If each country has reached the individual re-order point, is the global re-order point reached as well?

To answer the above questions, it is necessary to have insight into the policies and scenario's that the individual Armed Forces use or will use.

(3) Is the global re-order point reached and can I wait for delivery? See also *global decision* point 2 above. The establishment of the re-order point and the decision on whether to wait is acceptable, and depends largely on the policies and the logistic scenario that are in use and will be used.

(4) Delivery by another Armed Force? This triggers another question, namely, when is another Armed Force able to supply me or in which situation(s) is it useful to redistribute and when not? For example when redistributing from one country causes a need in that country at a later stage, then redistribution makes no sense. As there must be another redistribution made to satisfy the country which had earlier offered his stock. A kind of "snowball effect" could arise. Also in the case where a large Armed Force has a need and, seen globally, there is enough stock to satisfy its need, the stock could be dispersed through all the smaller Armed Forces. In this case the items must be redistributed from all corners of the system in small numbers. The large Armed Force "consume", as it were, the stock of the small Armed Forces. Under these conditions investigation must be made as to whether distribution makes sense or not.

(5) Is the item still needed? See *global system* decision point 3, above, but here on a local basis.

(6) Is the present stock level too high? As long as the, global as well as the local, policies and logistic scenarios are not known, this question cannot be answered (see *global system* decision point 2 above). In cases where the item is a part of a higher assembly, the considerations related to the *global system*, decision point 3 above, apply.

(7) Is there a demand/need in another country? See decision point 6.

Action points:

(a) sell/redistribute. The same questions as already mentioned under *local system* decision point 4 above, came up. In phase one of COMMIT, when the Armed Forces have different inventory prices for the same item, what will be the selling price for this item?

(b) reduce stock. It is assumed that SHARE is the major tool for stock reduction. But still questions as to what price will the items be sold arise? SHARE is only a solution if the participating Armed Forces in SHARE are not the same as in COMMIT. Otherwise the stock has to go back to the supplier if possible, or be scrapped.

(c) remove from stock. As (b), but now the total stock must be removed.

(d) Practical problems: These are problems which could come up during operation of the COMMIT system. Even so, service levels are set in both stock control systems (central and decentral) it could be that material requirements cannot be filled from existing stocks. If this would be the case, actions have to be taken by the users themselves to cover those requirements. Those actions could for example be temporary use of a substitute product or cannibalisation

3.4 Situation COMMIT

COMMIT was introduced to the BoD in July 1996. By mid 1997 a concept approval was ready and a feasibility study was presented to the BoD in July 1997.

The purpose of the feasibility study was to provide the necessary information to allow the BoD to take a decision on whether or not to approve the implementation of the COMMIT concept and system. The study was to respond to three basic questions, namely:

1. Are the potential benefits as significant as suggested in the initial feasibility study?
2. Can it be done from an EDP point of view?
3. Is there support for the concept from the Armed Forces?

The first question, *"Are the potential benefits as significant as suggested in the initial feasibility study"*, is the key issue in this study. An initial feasibility study was done at an earlier stage (Oorebeek January 1996). Table 3.1 gives a summary of the total quantified benefits published in the initial feasibility study. These benefits are based on a number of 2.7 million common items (NSN's) in NATO. The total number of registered NSN's is more than 12.5 million item.

Table 3.1: Summary of expected benefits of COMMIT

	SUMMARY BENEFITS in US Dollars	
Category	Annual	5 years period
reduced risk excess	18,031,800	90,159,000
less investment for same service level	36,063,640	180,318,200
reduction of Annual Turn Over Value (ATOV)	28,939,920	144,699,600
better supplier conditions	95,094,750	475,473,750
Total	**124,034,670**	**620,173,350**

source: NATO common item material management programme, project COMMIT, feasibility study proposal, page 42, (NM(96)BOD/31)

To prove potential benefits, six countries have offered to participate in the study. These six countries are Belgium (BE), Denmark (DK), Germany (GY), Netherlands (NE), Norway (NO) and United Kingdom (UK). For DK, GY, NE and NO, the armies as well as the air forces of the countries participate in the study. For BE only the army participate and for UK only the air force. First, the commonality between the Armed Forces was analysed. For items with a commonality between the five armies or the five air forces the following data is collected from each Armed Force:

- NATO stock number (NSN)
- Quantity in stock (QTY)
- National Item Category Information, is an item repairable Yes or No (NCD)
- Unit of issue (UOI)
- Unit Price in US$ (UPR)
- Demand data of the last 8 quarters
- Number of demands in the last 8 quarters
- Source of supply (SOS)
- Total Quantity in pipeline, in case of repairable item (SLP)
- Stock level safety stock (SLS)
- Stock level re-order point (SLR)
- Stock level operating stock (SLO)
- Procurement lead time (PLT)

Where a study sample is mentioned in this report, it refers to the data of the common items between the five armies. Some simple analyses (Oorebeek February 1997) has already been done with this data. The conclusion from these analyses is that the total sum of stock level calculations per each individual Armed Force was higher than the global stock level calculations. This is a direct result of a more reliable statistical baseline, if consolidated.

A calculation of the exact savings was not possible. To invest a more realistic estimation of the savings, first the questions (§3.3) about the control system, must be answered. The questions are related to three main problem areas:

1. *What are the current policies and scenario's in the individual Armed Forces and what will be the final logistic scenario and policies for the consumable items?*

2. *What is the result if the RI's are considered into COMMIT?*

3. *How to handle surplus stock?*

After the interim presentation it was decided to make a deeper study into the RI's. The reasons for this are as follows, namely:

- It arose from the still existing questions in the COMMIT proposal (§ 3.3), concerning the dependency between the repairable and consumable items.

- The different way's of processing the repairable and consumable items. A study concerning the consumable items was already in progress.
- From the first study sample it could be concluded that items which are repairable in one of the five Armed Forces represents a stock value of 60% of the stock value of the items.
- A concept of the feasibility study had to be ready at the end of April, this did not fit into the time planning of the thesis project.

The remaining report will focus on the repairable items. Chapter 4 will concentrate on the causes of this decision.

Chapter 4

Final assignment

4.1 Introduction

This chapter covers phase 1 *("formulating the mess")* and phase 2 *("ends planning")* of the study (Chapter 1). Here it will be explained why more research into repairable items is necessary. Also the "goal" to be achieved is described. Finally the establishment of the study framework is examined. From the current situation, the scope and the framework, the final assignment is derived. At the end of this chapter, research questions are listed, those questions need to be answered to build a reliable model.

4.2 Reasons for more research into the repairable items

One reason to do more research into the repairable items is the dependency of the whole system, the sub assemblies (repairable items) and the consumable spare parts (Chapter 4), on repairable items. A second important reason why more research is advisable, is the enormous amount of money that is involved in the stock values of these items.

The total value of the items in stock from the study sample, which are considered as repairable in all the five armies is more than 56,000,000 US dollar. This represents more than 20 % of the total stock value of the 5,120 line items which were selected for the COMMIT study. On the other side, the number of items is only 60 out of 5,120 , representing only 1.2 % of the total items. In addition to that, there are 1,031 items out of the 5,120, which are considered as repairable items in at least one of the participating armies. These items, with an actual stock value of around 99,000,000 US dollar, represents more than 35 % of the total value (table 4.1 Stock values of repairable items versus consumable items).

table 4.1: Stock values of repairable items versus consumable items

	number of items	% of total number of items	actual stock value	% of total stock value
repairable in all five armies	60	1.17	56,436,353.70	21.01
repairable in at least one of the armies	1,031	20.14	99,040,389.69	36.87
consumable in all five armies	4,029	78.69	113,156,021.92	42.12
total	**5,120**	**100**	**268,632,765.31**	**100**

From these results it may be concluded that repairable items are an important part of the total stock value and therefore it is necessary to consider them within the study.

As can be seen from the study sample, an item can be considered as a RI in one Armed Force, while the same item is considered as CI in another Armed Force. Thus the decision criteria on whether an item will be repaired or not, are different.

Both groups, repairable in all five armies and repairable in at least one of the armies, are studied in more detail. The first group is studied because of the relatively high stock value. A small part of the number the NSN's (1.7%) represents a stock value of 21 % of the total stock. The second group is studied because of the relatively high value too, but also because it is expected that a certain cost reduction can be achieved, by just making small investments. For example, considering an item repairable instead of consumable or the opposite.

4.3 Description current situation

A clear and fully valid description of the current situation should be a description of the logistic policies and scenario's used in the individual Armed Forces. As already mentioned, this will take an enormous amount of time and energy. And even than, it is not certain that the required description of the current situation can be discovered. Further the middle management persons in the Armed Forces changes often and knowledge about applied policies and criteria's for decision making is often not transferred..

In this paragraph, the exact current situation will not be described. The current known issues, which are important for this research are discussed.

A known general issue of course, is that each Armed Force control their own RI (and CI) system. As already stated, the policies used in the individual Armed Forces are different from each other. The Armed Forces use different sources of supply and repair, and also pay different prices for procurement and repair, and this leads to the different policies. This also plays a role in the decision making, depending on whether or not an item is repairable.

COMMIT is meant for all common items. A small part of the common items are already jointly managed within existing Weapon System Partnerships (WSP's). When several nations using the same weapon system then they often create WSP's. All partners need repair services and spares equally in order to keep the equipment operational. Actually all WSP's work individually so there is practically no interaction between the several WSP's. They are not always in a position to know which items, how many items and the value of the items which occur in more than one weapon system.

Two weapon systems are used in all five participating armies, the Leopard (Tank) and the M113 (Armoured Personnel Carrier). For both weapon systems, there is no WSPC. The commonality of both weapons results in, the items used in the study sample are mainly items from these two weapon systems. A table indicating the weapons used in at least one of the five Armed Forces, which participate in the study is provided in appendix III.

4.4 Framework for the study

The goal of this study is to provide insight into the prospect of including the RI's in COMMIT. It would also like to examine what the advantages and disadvantages are, concerning the availability and costs.

Within COMMIT, each individual Armed Force will manage its local inventory system. The global inventory system will be managed by NAMSA. This means that only the national levels are important for this research, and thus only the activities on national levels will be considered.

At the start of my thesis period, data collection for the study was already in progress. Data sets were collected from the participating Armed Forces. As collecting data takes an enormous amount of time, this research was started by using the same study sample, namely the sample of 5,120 NSN's which are common between the armies of BE, DK, GY, NE and NO.

The study does not include procurement analysis. Procurement analysis are included in the study concerning the CI's. The benefits of joint procurement of CI's can be projected to RI's.

In a second step, where more data about RI's is needed, the study will be continued with the Armies of BE, GY and NE, but only for a small sample (around 20 items). The first limitation, to restrict the study to BE, GY and NE, is made because of practical reasons such as individual discussions with Armed Forces, data availability and clarity. The second limitation, only a small study sample, is made because after discussion with the representatives of the Armed Forces, it seemed that data about RI's must be collected manually. This alone will take too much time.

4.5 Description final assignment

The final assignment is:

> *"Develop and evaluate models which support the decision on whether an item will be considered repairable or consumable. and, if the item is considered as repairable, in which situations is consolidation of repairable items advisable?"*

The assignment can be divided into four parts, namely:

1. Develop a model which supports the decision repairable item or consumable item
2. Develop a model which gives insight into the number of items needed in a repair loop, to achieve a certain service rate.
3. Apply both models for a selected group of items.
4. Evaluate both models

The issues 1 and 2 correspond with phase 3 *("the means planning")* of the study, issue 3 corresponds with phase 4 *("resource planning")* and a start of phase 5 *("design of implementation and control")*. The last issue, evaluate both models, is also part of phase 5, the control part. For an explanation of the study phase, see Chapter 1.

4.6 Research questions

For each part of the assignment, research questions are formulated. These research questions will be answered to come to a satisfactory result.

Develop a model which supports the decision repairable item or consumable item.

1. Which parameters may influence the decision repairable or not?
2. How do these parameters influence this decision?
3. Combine the found parameters in one model.

Develop a model which gives visibility into the number of items needed in a repair loop, to achieve a certain service rate.

1. What are the performance criteria for consolidation for repairable items?
2. How could these criteria be measured objectively?

Apply both models for a selected group of items.

1. Which items are interesting for detailed research?
2. What would be the difference if an item is treated as a repairable or as a consumable in terms of Run Out Times?
3. What makes the difference in costs?

Evaluate both models.

1. Could the models be used the way they are developed?
2. What are the reasons that the model can be or cannot be applied as expected?
3. What are the change off adjustments to be made to apply the model?

These questions must be answered for both developed models.

Chapter 5

Design of the model: Decision repairable or not

5.1 Introduction

This chapter focuses on the design of a model which supports the decision whether an item will be considered as a repairable item or as a consumable item .

In the first paragraph (§ 5.2) parameters which may influence this decision are discussed. In the second paragraph, steps which have to be taken in the model are presented.

5.2 Possible influence parameters

In co-operation with representatives of the participating Armed Forces and experts in the organisation, the parameters which may influence the decision as to whether an item will be considered as a RI or as a CI are collected. The following list shows all the relevant parameters (unsorted criteria).

- (remaining) life cycle
- procurement lead time
- procurement price
- repair time
- repair price
- demand figure
- scrap rate
- general maintenance policies
- operational concept
- manufacturing capability
- phase out/obsolesce
- modification
- availability

(Remaining) life cycle
At this stage of COMMIT, only existing items are considered. For this reason this parameter is not the life cycle, but the remaining estimated life cycle. If the current quantity in stock is sufficient to cover the remaining life time of the item, or the system in which the item belongs, the item can be considered as a CI.

Procurement lead time, procurement price, repair time, repair price
If an item is difficult to obtain, the lead time could be extremely long and to repair the item will often be the only alternative. But this can only be considered if the repair time does not exceed the procurement lead-time. The procurement time and repair times must be seen in relation to procurement prices and repair prices when a decision if the item is repairable or not has to be taken. Often, a low procurement price may also result in a long procurement lead-time.

Demand
If the demand is low, it is often not feasible to invest in individual national repair facilities. A possible alternative would be, to send the item to a contractor. But if the demand is extremely low, there may be no suitable contractor available.

Scrap rate
The scrape rate is defined as the number of failed items which **cannot** be repaired, divided by the total number of failed items. A scrap rate of 1 (100%) means, none of the items were repaired. In cases where the scrap rate is 0 (0%) all the items can be repaired.

General maintenance policies
Often Armed Forces use generalised policies to decide whether an item is repairable or not. For example, the policy that if the estimated average repair price, divided by the procurement price is higher than a certain percentage, the item will be a consumable item.

If repairable items become part of COMMIT, these general maintenance policies must be (on the national level) the same for each participating Armed Force.

Operational concept
The operational concept prescribes the physical location of each item to be stocked. Armed Forces usually utilise "echelons" or a hierarchical concept. The operational concept also details how many items are stocked on each echelon, and also which repairs can be done on which echelon.

Repair facilities
The decision as to whether an item will be considered as repairable or consumable depends also on the already available repair facilities. An existing repair facility with sufficient capacity to repair the item will stimulate the decision for repair. The additional investment costs may be the decision parameter.

Manufacturing capability
In cases where an item is not manufactured any more, the item must be considered as a repairable item. This parameter can be combined with the procurement lead time. If an item is not manufactured any more, the procurement lead time will be infinite, and the item must be considered as a repairable item. Also when the manufacturing capacity is insufficient compared with the demand for an item, the procurement lead-time may increase and as a consequence, at some stage an Armed Force may be better off by considering the item as a repairable.

Phase out/obsolesce
A phase out of a system is always a planned period, during which the number of item in use are reduced or replaced. This can be done because of a modification. All items which have the old configuration are disposed, and a new configuration is introduced.

This parameter can be considered in combination with the remaining life cycle of the weapon system or item. If an item is obsolete, and is replaced by a substitute, the obsolete item will not be repaired. Often during a phase-out period, to control the logistic system, weight factors are used for the part that still has the old configuration, and the items that have already the new configuration. If the number of items with a new configuration grows, the weight factor will decrease.

Modification
Three reasons, within the scope of this study, why modifications takes place:

1. To improve the Mean Time To Replacements (MTTR)
2. To make the item/system more repair friendly
3. To improve the function of the system/item

ad 1
In this case, if the MTTR decreases, less items are needed and thus less items will be procured and/or repaired. It can be, because of the decreasing of the number of repairs, that it makes no sense to continue to invest in repair facilities.

ad 2
The second reason, a modification to make the item more repair friendly, means that the repair time reduces. It could even be that, because of modification, the repair rate increases, thus having as a consequence a reduction of the overall scrap rate.

ad 3
The improvement of the function does not directly influence the Mean Time To Replacement of the item. But it could be that an improvement of the function leads to an improvement of the Mean Time To Replacement of another item in the system.

If an item is modified, the process for decision making (whether an item is repairable or not), must be repeated. If modifications are known in advance, at the first time the decision process is done, the expected modification could be considered in the first analysis.

Modification could have great influence on a logistic system. The cause of the influence is based on Direct Exchange (DX) or Indirect Exchange (IX). Direct Exchange means that as soon as an item is send to a repair facility, a new (repaired) item is send directly back to the Armed Force. Indirect Exchange means, that if an item is send to a repair facility, (exactly) the same item must be send back. It will be clear, if we compare DX and IX, the time before an Armed Force receive a serviceable item is much shorter when DX is used. But one important requirement to use DX is that all the participating Armed Forces must use items with the same configuration. Thus if an item is modified in one Armed Force, the same modification must be done in all the other Armed Forces.

Availability
The performance criteria for logistic control systems is usually to achieve the highest availability for the lowest costs. If the decision, repairable or consumable, must be made, the availability must be considered as well.

The influence parameters are depending of each other. For example the procurement lead times and prices. In table 5.1, can be seen which parameters are depending of each other.

Table 5.1: The dependence between the influence parameters.

	Remaining life time	Procurement lead time	Procurement price	Repair time	Repair price	Scrap rate	Replacements	General maintenance policies	Operational concept	Manufacturing capabilities	Phase out/obsolete	Modification	Availability	Available repair facilities
Remaining life time	x						x				x	x		
Procurement lead time		x	x	x	x	x	x			x			x	
Procurement price		x	x	x	x	x	x			x				
Repair time		x	x	x	x	x	x	x				x	x	x
Repair price		x	x	x	x	x	x	x				x		x
Scrap rate		x	x	x	x	x	x	x			x	x	x	x
Replacements	x	x	x	x	x	x	x	x	x	x	x	x	x	x
General maintenance policies				x	x	x	x	x				x		x
Operational concept							x		x				x	x
Manufacturing capabilities		x	x				x			x	x	x	x	
Phase out/obsolete	x					x	x			x	x	x		
Modification	x			x	x	x	x	x		x	x	x	x	x
Availability		x		x		x	x		x	x		x	x	x
Available repair facilities				x	x	x	x	x	x			x	x	x

From this table it can be concluded that all the parameters influence each other, if not directly, than indirectly. The most difficult point in the decision process is the fact that such parameters are not known or can not be quantified. These parameters are the general maintenance policies, operational concept, manufacturing capabilities, phase out, modifications and available repair facilities. These parameters will indirectly be considered in the model. For example insufficient manufacturing capability may lead to increase of the procurement prices and lead-times. The procurement prices and lead-times will be considered in the model.

5.3 The model

The developed model is composed of three steps. In each step, it can be concluded that an item needs more research, or a decision can already be made as to whether the item is repairable or not. If, after a particular step, it becomes clear that no more research is required to make the decision repairable or consumable, remaining steps do not have to be followed.

The first step is based on the expected demand and the remaining life cycle of the weapon system in which the item belongs. The second step will consider the procurement and repair prices and lead times. The last step is based on a cost indication.

One of the requirements in this model is that the repair task on national level are the same tasks, or at least comparable with each other.

5.3.1 Step 1: Evaluation of current stock level

The expected remaining life cycle of an item depends on the remaining life cycle of the weapon system in to which the item belongs. An item can be considered as CI if the serviceable stock level in the Armed Forces is equal to, or higher than the total estimated demand during the rest of the life cycle of the weapon system. Usually it is difficult to estimate the remaining life cycle of a weapon system, and if this is possible, it is even more difficult to estimate the demand during the time that elapses until the end of the life cycle time. An indication of the stock level compared to the demand will be done.

In connection with the NAMSA definitions of excess stock (stock position > 10 year) and long supply stock (stock position 5-10 year) the following policies are established. If the serviceable stock is sufficient to cover 10 years or more, the item will be considered as "consumable". If the stock position is between 5 and 10 years, the item will temporarily be considered as "consumable". A "temporary consumable" item is for example an item that is consumable until an established stock level is reached. Another meaning of temporary can be that the failed items will be kept in unserviceable stock, so that repair at a later stage can be done. The aim of considering an item to be "temporary consumable" is to reduce the stock positions.

Items with a global stock position of less than five years will be subject for research in more detail in the next step.

5.3.2 Step 2: Comparison of repair and procurement parameters

This step consists of a comparison of the parameters:

- procurement lead time (PLT)
- procurement price (PP)
- average repair time (ART)
- average repair price (ARP)

A comparison of the procurement price and the repair price is an obvious step. To combine the four parameters in one step is necessary because of the possible interaction between the prices and the lead-times. For example, an item can be expensive to obtain because of a required short lead time (see also §5.2). In this step, a decision can be taken for an extreme situation. For a less extreme situation, this step must be seen as an indication about the ratio's between parameters.

In figure 5.1 a graph is drawn to support this step. The x-axis represents the PLT divided by the ART and the y-axis represents the PP divided by the ARP. For extreme situations the decision is not difficult to make. If the PP is low compared to the estimated ARP, and also the PLT is low compared to the ART, the item will be a CI. In the opposite situation, a high PP compared to the ARP and a long PLT compared to the ART the item will be considered as RI.

For the sections in the right upper part and the left lower part (figure 5.1) a decision can easily be made. The lines drawn in the figure are established by discussion with representatives of the participating Armed Forces and experts on this area in the organisation. The motivation of the establishment of the section was that an incredible long procurement lead time will lead to consider an item repairable, independent of the repair price. At this point, the influence parameter of the manufacturing capabilities is indirectly considered. If no manufacturing capability exists, the PLT is infinite and the PP will also be high, thus the item is considered as a repairable item.

The sections indicated in the figure by question marks are the ones where a clear decision as to whether the item is repairable, can not clearly be made. For this section a cost comparison may be made in step 3 of this model.

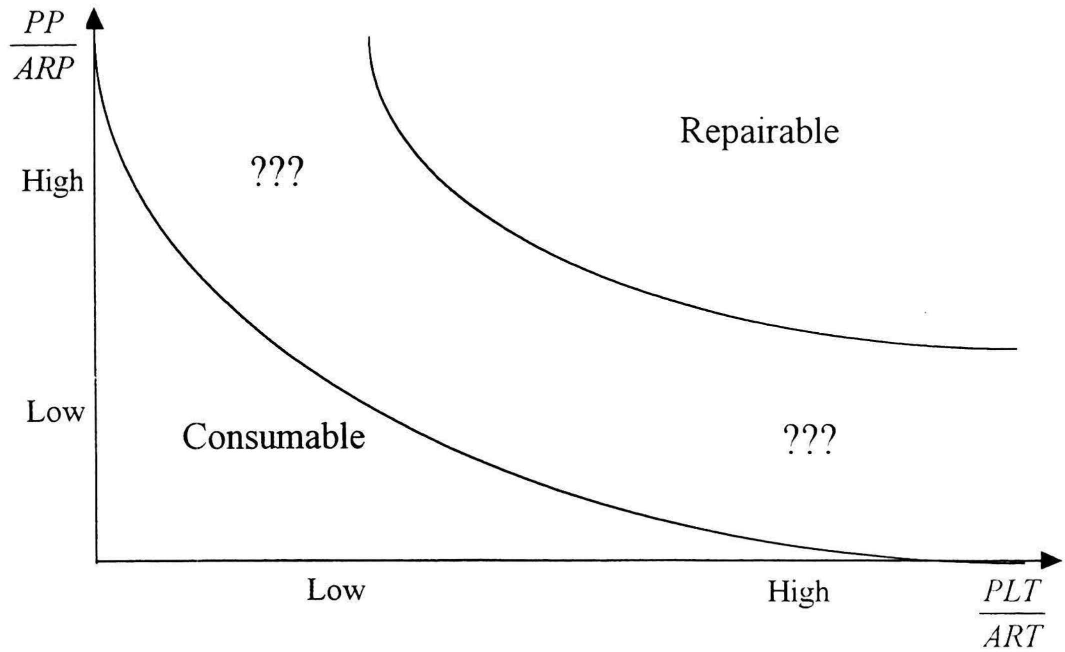


Figure 5.1: Consideration of Procurement Price (PP), Procurement Lead-Time (PLT), Average Repair Price (ARP) and Average Repair Time (ART),

5.3.3 Step 3: Cost analysis

The final step in this model is a cost comparison. All costs which arise during the life time of an item must be considered. From an economical point of view, the total costs for the different item control management system must be compared. But it is difficult to collect all costs. Also to collect information about the existing repair facilities is difficult. If information can be provided about the repair facilities, it is even more difficult to provide information about the capability and/or capacity of the repair facilities. Thus information about potential additional investment (i.e. whether repair facilities will expand), can not be estimated, as some Armed Forces will repair their own items.

The cost often depends on which inventory control system is used. Five control systems are distinguished, namely:

- consumable consolidated
- repairable individual self
- repairable individual contractor
- repairable consolidated self
- repairable consolidated contractor.

For consumable items, only a consolidated situation is observed. This is because in earlier research it has already been demonstrated, that the common item management of consumable items is preferable above individual management (Oorebeek June 1997). This is mainly because of availability and cost aspects. If the consumable items are consolidated, a higher availability can be achieved for lower costs. This is caused by a more reliable statistical baseline.

For the repairable items, the reason why the individual and consolidated situations are distinguishable is clear. The discrimination between self repair (i.e. by the Armed Forces themselves) and contractor repair is made because of the cost of repair prices. If an item is repaired by a contractor, the exact repair costs are not known. Only the prices which the Armed Forces have to pay are known. These prices could not be compared with the costs if the items is repaired by themselves.

Within the framework of this study, it is not possible to discover all relevant costs. A simple comparison can be made between the costs if an item is repairable or not, expressed in the number of replacements.

Costs if repairable: $E_{rep}(Cost) = Q \cdot s \cdot P_{proc.} + Q \cdot (1-s) \cdot P_{rep.}$

Costs if consumable: $E_{cons}(cost) = Q \cdot P_{proc.}$

Here:

$E_{rep}(cost)$	=	The estimated costs if the item is considered as a repairable item.
$E_{cons}(cost)$	=	The estimated costs if the item is considered as a consumable item
Q	=	The number of replacements
s	=	The scrap rate
P_{proc}	=	The procurement price
P_{rep}	=	The average repair price

If there is decided that the particular item will be considered as repairable item, the (additional) investment must be equal or lower than the difference between the estimated costs. The model in this chapter is developed for the items which are repairable in one Armed Force and consumable in a different Armed Force. Thus information about repair prices can be obtained by the Armed Forces where the item is repairable. To make these comparison, it must also be known whether the repair prices is based on self repair or contract repair.

5.4 Life Cycle Cost Analyses

A possible guideline to cover all the costs concerning an item during its 'life', is the Life Cycle Cost Analysis (Blanchard 1992). A Life Cycle Costs Analysis is defined as a systematic analytical process of evaluating various alternative courses of action with the objective of choosing the best way to employ scarce resources.

In general, life-cycle cost includes the following cost categories: Research and Development costs (C_R), Investment costs (C_I) and Operations and Maintenance costs (C_O) see figure 5.2.

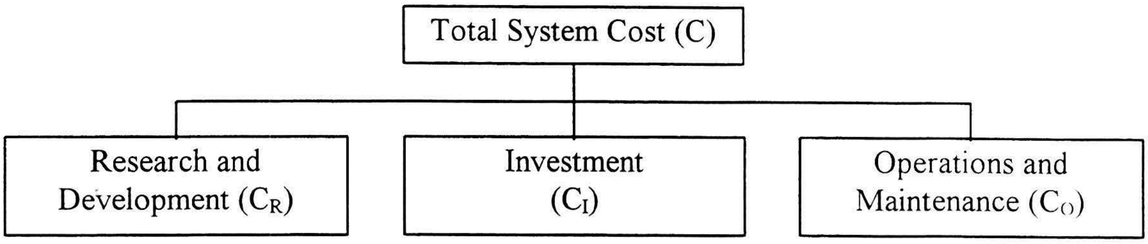


Figure 5.2 Cost Breakdown of Total System Costs

The aim of looking into these costs, is to get insight into which costs are high and which costs are low for which control system. Below is summarised which additional costs increase or decrease per item using the different control systems. In appendix IV, a detailed description of each cost category is discussed. Also the influence of each sub-cost-category is given in the appendix.

Research and development cost (C_R); Includes all costs associated with conceptual/feasibility studies, basic research and development, advanced research and development, engineering design, fabrication and test of engineering prototype models (hardware), and associated documentation. Also it covers all related program management functions. These costs are basically non-recurring costs.

In this phase of COMMIT, the potential item management systems for existing items will be compared. The costs made in this stage of the life cycle are already made and can not be influenced any more. The research and development costs will not be further considered.

Investment cost (C_I); Includes all costs associated with the acquisition of systems/equipment (once the design and development has been completed). Specifically this covers manufacturing (recurring and non-recurring), manufacturing management, system construction, and initial logistic support.

Investment costs must be included because the manufacturing costs are part of this cost category. The total manufacturing cost will decrease, if an item is considered as repairable instead of consumable. But the cost per item will increase in this situation

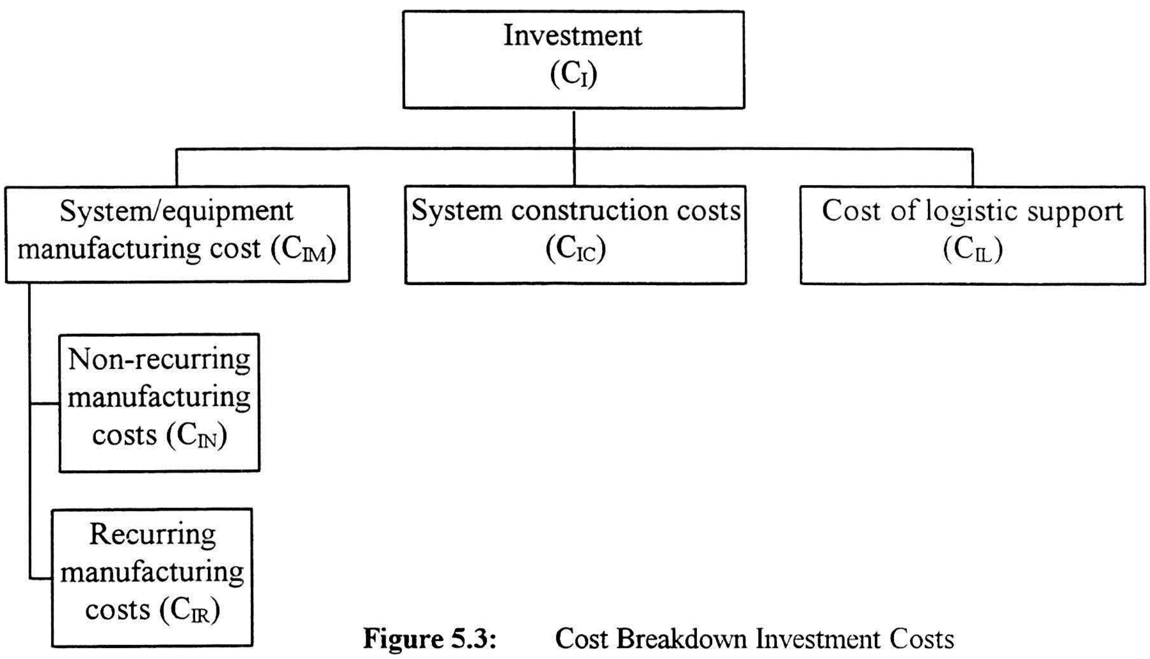


Figure 5.3: Cost Breakdown Investment Costs

Non-recurring manufacturing costs (C_{IN}):
Includes all fixed non-recurring costs associated with the production and tests of prime systems/equipment's. Specifically, this covers manufacturing management, manufacturing engineering cost, tools and factory test equipment (excluding capital equipment), quality assurance cost, cost of qualification test, cost of production sampling tests.

These costs can not be influenced anymore, thus further consideration of these costs are not done.

Recurring manufacturing costs (C_{INP}):
Includes all recurring production costs as recurring manufacturing engineering support costs, production fabrication and assembly labour cost, production material and inventory costs, inspection and test costs, packing and initial transportation costs.

The recurring manufacturing costs per item will not change. Independent of which inventory management system is used, each item must be manufactured. In the long run, the recurring manufacturing costs will decrease when the item is an RI. This because less items have to be manufactured than if the item were a CI. But in the short term, not all the costs will decrease. In the short term only the variable part of the cost categories will decrease. These are costs like the production material, packing material and transportation fuel. The fixed costs, for example buildings, transportation vehicles and existing labour contracts etc., need a longer time to decrease.

Construction costs (C_{IC}):
Includes all initial acquisition costs associated with manufacturing, test, operational and/or maintenance facilities (real property, plant, and equipment) and utilities (gas, electricity, water, telephone etc.).

These costs differ for the various control systems. For example, the investment for the maintenance facilities depends mainly on whether the item is repairable or not. When an Armed Force is managing an item as a consumable item, and then subsequently changes to managing it as a repairable item, because of consolidation, it is probable that manufacturing facilities must expand. This would have the result of increasing the manufacturing facility costs.

Initial Logistic support cost (C_{IL}):
This includes all integrated logistic support planning and Control functions associated with the development of system support requirements, and the transition of such requirements from supplier(s) to the applicable operational site. Also included are the costs related to logistic program management cost, cost of provisioning, initial spare/repair part material cost, initial inventory management cost, cost of technical data preparation, cost of initial training and training equipment, acquisition cost of operational test and support equipment, initial transportation and handling cost.

Generally, the initial logistic support costs will increase if the item is considered as a repairable item. In the consolidated situation, these costs will further increase. The exception to this is the costs of provision, which includes the costs of preparation of data which is needed for the procurement of spare/repair parts and test and support equipment. Those costs will decrease because of the consolidation. When the situations of self repair or contractor repair are compared, the initial logistic support costs for self repair increases (in several cases) more than if a contractor repairs the item.

Operation and maintenance cost(C_O); Includes all costs associated with the operation and maintenance support of the system throughout its life-cycle subsequent to equipment delivery in the field. Specific categories cover the cost of system operations, maintenance, sustaining logistic support, equipment modifications, and system/equipment phase-out and disposal. Costs are generally determined for each year throughout the life cycle.

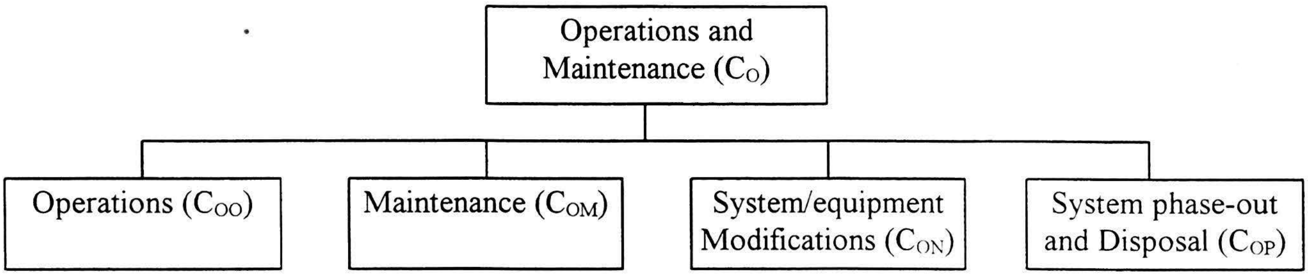


Figure 5.4 Cost Breakdown Operations and Maintenance Costs

Operations (C_{OO}):
Includes all costs associated with the actual operation (not maintenance) of the system throughout its life-cycle. Included here are the operating personnel cost, the cost of operator training, costs of the operational facilities, cost of support and handling equipment, (this includes the equipment needed for corrective as well for preventive maintenance).

These costs will in general be equal, notwithstanding the type of control system. Only the costs associated with support and handling equipment will increase if the item is considered as a repairable item.

Maintenance (C_{OM}):
This category includes all sustaining maintenance labour, spare/repair parts, test and support equipment, transportation and handling, replenishment training, support data and facilities necessary to meet the maintenance needs of the prime equipment throughout its life cycle. Such needs include both corrective, and preventive maintenance, requirements.
If an item is considered as a repairable item, the maintenance costs will increase.

System/equipment Modifications (C_{OM}):
Throughout the system life-cycle after equipment has been delivered in the field, modifications are often proposed and initiated to improve system performance, like the MTTR or to make the item more repair friendly. This cost category includes modification kit design (R&D), material, installation and test instructions, personnel and supporting resources for incorporating the modification kit, technical data change documentation, formal training (as required) to cover the new configuration, spares etc. The modification may affect all elements of logistics.

The influence of these costs on the type of control system cannot always be estimated. It can however be said that generally in the long term the expected costs decrease if a modification is introduced.

System phase-out and Disposal (C_{OP}):
This category covers the liability or assets incurred when an item is condemned or disposed. This factor is applicable throughout the system/equipment life-cycle when phase-out occurs. This category represents the only element of cost that may turn out to have a negative value, resulting when the reclamation value of the end item is larger than the disposal cost.

The system phase-out and disposal costs include the negative costs which will be the income when selling to, for example, a second hand buyer. But nowadays, not only material costs should be considered, but also disposal costs because of environmental constrains and the additional costs sometimes linked to this.

After considering all the costs, the general impression is an overall increase of costs if the item is considered as a repairable item. This is a logical result, because the discussed costs are the costs which do arise for one item during its life time. If an item is considered as a repairable item, the life time of the item is longer, thus the costs to sustain it during its life time is higher. But on the other side, if the item is an RI, **less items have to be procured**. To know the total number of items required, the scrap rate and the number of items needed in the repair loop must be considered.

5.5 Review model

This model is discussed with the aim of obtaining an indication about the way parameters may influence the decision "repairable or not?". There will always be an area where it makes only a small, or even no, difference by considering an item repairable or consumable.

In paragraph 5.4, the introduction of the Life Cycle Cost Analysis, is included to obtain insight in which costs increase and/or decrease by introducing a consolidated stock management for repairable items.

The model is primary developed to decide whether the item will be considered as repairable or consumable. This applies to existing common NSN's (which are repairable in at least one of the Armed Forces and consumable in another). If a new NSN is introduced, this model can also be used, but the parameters must be estimated. This can be done for example with the use of experiences with a similar item, or information provided by the manufacturer.

The model will be applied for a certain groups of NSN's. The results will be discussed in Chapter 7. In this chapter, the utilisation of the model will also be discussed.

Chapter 6

Turnaround model

6.1 Introduction

In this chapter, an algorithm to calculate the number of required turnaround items is explained. The algorithm is based on a combination of the classical queuing theory and the Markov routing (Senden 1995).

The repairable loop will be modelled as a closed system with two multi server stations and a fixed number of items in the system. The multi server stations are the usage process and the repair process.

Paragraph 6.2 describes why the algorithm which is explained in this chapter was chosen. A description about the current and future situation and how the model will look like is given in paragraph 6.3. Afterwards, the assumptions which must be made to apply the model are discussed. The chapter will finish with a description of the mathematical background of the model. A part of the mathematical background is inserted in the appendixes.

6.2 Model selection

The aim of the model is to investigate whether consolidation of repairable items make sense. In this stage of the COMMIT project, this is the first study concerning the potential logistic advantages of including repairable items in COMMIT.

To discover a first impression of the potential benefits, a simulation study and a mathematical approach are considered. Both methods should give the required information. This is chosen for a mathematical approach because the expected time a simulation model will cost, is much longer compared to the expected time to perform a mathematical calculation

Several algorithms are considered to calculate required "stock levels" to achieve a certain service level. Stock level is written between quotes because the meaning varies depending upon the way it is used. Most of the considered algorithms were too detailed, so that too much information was needed and often focused on a multi echelon system. For example the Multi-Echelon Technique for Recoverable Item Control, METRIC (Sherbrooke 1968).

The turnaround model discussed in "Planning and control in the Maintenance of groups of similar objects" (Geraerds 1990) is a model to calculate the number of turnaround items needed in a repair loop. This model has the advantage that not many parameters have to be known, but cannot be used to prove the consolidation effect. This is because the maintenance through put time is a fixed time, and independent of the number of items that can be maintained at one time. In other words, the potential prior waiting time is neglected in the model. Because of this fact, the total number of turnaround items needed for a certain number of individual Armed Forces will result in an equal number of turnaround items needed in one consolidated situation of the Armed Forces.

In "The Markovian Two-echelon Repairable Item Provisioning Problem" (Abboud 1996), an algorithm is explained to determine the optimal number of machines and repair channels at two repair centres to minimise costs and meet a service-level. The basis of this algorithm corresponds with the model discussed in this chapter, with the exception that only one echelon is considered.

6.3 Situation

In figure 6.1 a simplification of the current situation is drawn. This system is used in the individual Armed Forces. Thus the existing situation is a collection of these individual systems. These individual systems will be compared with one consolidated system in the new situation drawn in figure 6.2.

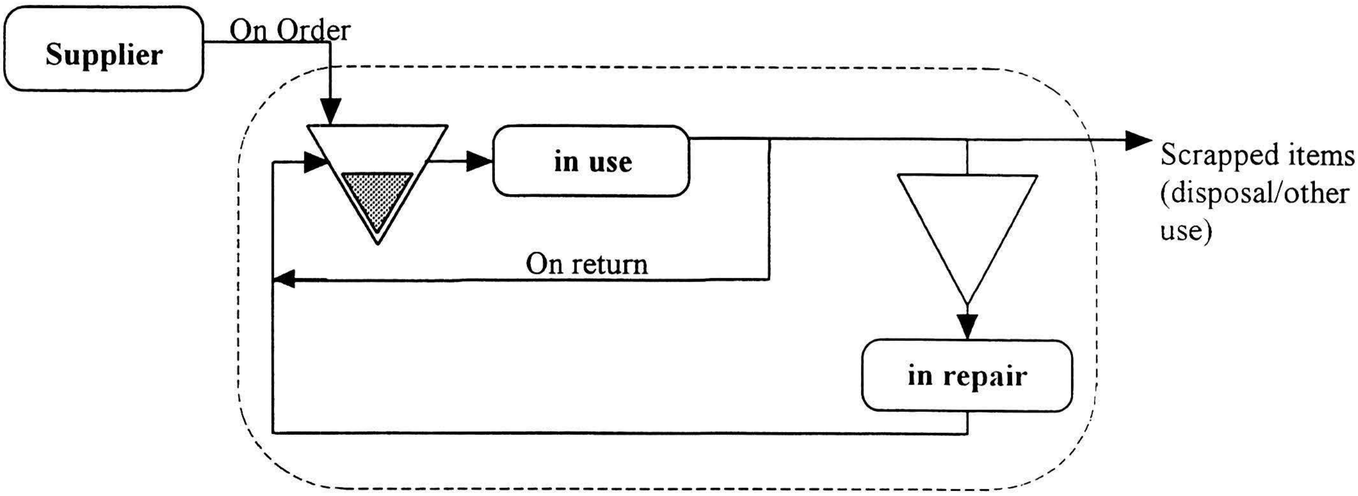


Figure 6.1: Current Situation

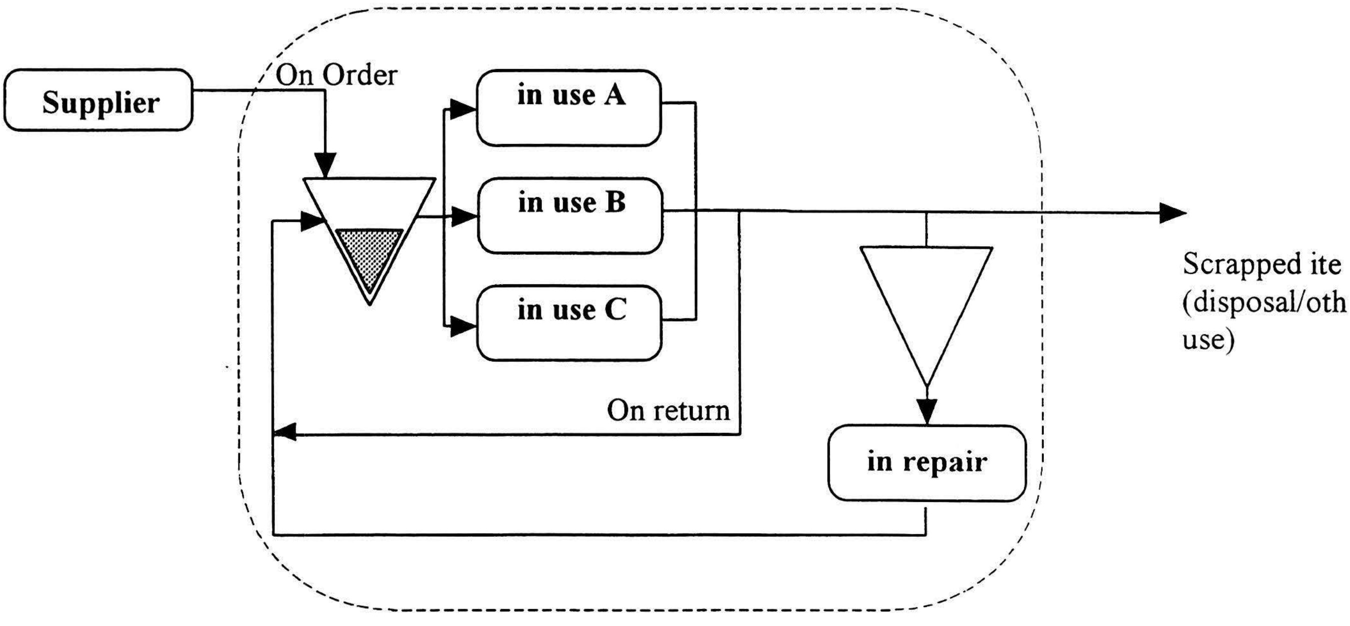


Figure 6.2: Consolidated situation

6.4 Assumptions

General:

- As soon as an item is scrapped, a new item enters the system.
- The number of items in use (operational items) is constant.
- The quality of an item is independent of the number of repairs.
- Only 'national' levels are considered.

For both stations:

- The "First Come First Served" (FCFS) discipline is used.
- The process follow a Negative Exponential (NE) distribution. The expected time in use is equal to $1/\mu_1$ and the expected repair time is equal to $1/\mu_2$ (thus NE distributed with parameters μ_1 and μ_2, where μ_1 is the expected number of failed items per time unit per server, and μ_2 is the expected number of repaired item per time unit per server) .
- The time in use and the repair time are independent of each other.
- After repair and after use, the items immediately leave the stations, lot for lot.
- There is no transport time between the stations[1].

6.5 Clarifications of the assumptions

As soon as an item is scrapped, a new item enters the system
This assumption is made to keep the number of items in the repair loop a constant.

The number of items in use is constant
In some Armed Forces, the density in the use of several weapon systems is decreasing. This results in a situation that repairable items, which belong to the particular weapon system, are send back to the national depot. This is the 'on return' line drawn in figures 6.1 and 6.2.
In the model, a 'steady state' situation is considered. In a 'steady state' situation a balance in the system is reached. If the number of operational items changes, the 'steady state' situation must be reached again and a new calculation has to be done. Because the aim of this model is to provide insight in which (general) situations consolidation of repairable items is preferable and also the decreasing processes of the individual Armed Forces are not known, the number of operational items will be assumed as a constant number.

Quality of repaired item
In the model is assumed that the quality of repaired items will not decrease (or increase) if the item is repaired. If an item cannot be repaired to a quality so that it can be operational for 100 %, the item must be scrapped and replaced by a new item.

Only 'national' levels are considered
Common item management is an approach to jointly manage the items on a **national** level. The individual control system will be managed by the individual Armed Forces (Chapter 3). The operational items are generally not used on the national level, but at a lower echelon. To come with the most reliable result, all the items in stock between the echelon where the items are used

[1] For the principals of the model, this assumption is made. In § 6.6 will be returned on these transport times

and the national level must be considered. It was not possible for the individual Armed Forces to provide this data, thus only the national levels can be considered.

First Come First Served (FCFS)
This means, when more than one item is waiting for repair, the item that arrived first, will be repaired first. This is the same for the usage process. In the research environment, this will probably not be done. Another discipline is probably used. After asking the participating Armed Forces, it seemed that it is almost never known what policies and disciplines they use. Even if they know their current policies and disciplines, it is hard to compare them to a consolidated situation with our policies, because it is not known which policies they will use in the present situation. The choice of the FCFS discipline for the usage process is a logical assumption, because each item in serviceable stock is equal.

Negative Exponential (NE) distribution
Repair times
If information can be provided about the repair times, this information exists from the average repair times. If no more is known about the repair time, the NE distribution must be assumed.

Mean Time To Replacement (MTTR)
In this model, corrective maintenance and preventive maintenance are combined. This is because the Armed Forces often could not separate them. Thus the MTTR can be influenced by the operational concept and the distribution of the MTTR.

The time in use and the repair time are independent of each other.
The same reason mentioned for the assumption of an NE exponential distribution, is valid for this assumption. A second reason that justifies this assumption, is the fact (discussed earlier) that no quality decrease takes place after repair.

After repair and after use, the items immediately leave the stations, lot for lot.
This is an assumption that must be made because the policies of the countries about batch sizes and order policies are unknown. To make a valid comparison, the policies in the individual situation and the consolidated situation must both be assumed equal.

From these clarifications can be concluded that most of the assumptions are justified because of the difficulty to provide accurate and up-to-date data.

6.6 Model

The model can be used to calculate the number of items needed in a repair loop to achieve a certain service level. The calculation is based on a combination of the classical queuing theory and a Markov routing (Senden 1995).

The repairable loop will be modelled as a closed system, this means that as soon as an item leaves the loop, a new item enters the system. Thus, the total number of items in the loop is fixed. In the loop, two processes are present. The process that an item is in use and the process that an item is repaired. Both processes are modelled by a multi-server station. A multi-server station, is a station where more than one server is available. For example a repair shop where five items can be repaired at the same time.

The usage process is modelled as a multi-server station, the *"usage station"*. The Mean Time To Replacement (MTTR) an item agrees with the operational time of one *"usage server"*. Also the repair process is modelled as a multi-server station, the *"repair station"*. The operational time of the *"repair server"* is the Average Repair Time (ART).

The services level is defined as the probability that all usage servers are busy. If we realise that the number of usage server is equal to the number of items that must be in use, this definition is justified.

The number of items needed in the process to achieve a certain service level will be calculated for each individual Armed Force. Also the number of items needed in a consolidated process to achieve the same service level is calculated. Both results will be compared to decide whether consolidation makes sense.

In an individual situation, the number of *"usage servers"* corresponds to the number of items that must be operational at the same time. The number of *"repair servers"* agree with the maximum number of items that can be repaired at the same time. In the consolidated situation, the number of *"usage servers"* is the sum of all the individual *"usage servers"*. The number of *"repair servers"* is also the sum of all the individual *"repair servers"*.

If the individual situations and the consolidated situation are compared, the total number of items in the consolidated situation must be smaller than the sum of all the individual number of items. And even the service rate in the consolidated situation must be higher than or equal to the individual service levels.

The mathematical derivation of the model is enclosed in appendix V

6.7 Transport time

In the discussed model, the transport times are neglected. This is a situation which is far away from reality. Two transport times can be distinguished:

1. Transport times between the servers.
2. Transport times which arise from "borrow activities (BA)": a borrow activity is defined as a re-allocation of stock from one Armed Force to another Armed Force (Copijn 1996).

ad 1; *Transport times between the servers.*
These transport times exist in both situations. The situation that Armed Forces manage their repairable items individually or consolidated. These times can be considered in several ways:

a) As two additional stations with an infinite number of servers
b) As two additional stations with a fixed number of servers
c) As a constant delay, a number of items will be added in the loop to cover the expected number of failed items during the transport time.
d) To include the transportation times in the work stations.

Each additional station in a Markov routing, makes the model much more complicated because the enormous increase of possibilities which arise by adding one new station. Therefore it is not chosen for the first two options.

The third option should be a good option to keep the model as simple as possible. But there is no experience with the influence on the results if the transportation time is considered in this way. For this reason, this option could not be used.

The transportation times will be included based on the fourth option. The transportation times will be included in one of the stations. However, this solution gives no clear answer, because adding the transportation time to the repair times means that during the actual transportation time the repair server is still busy. While in reality , the repair server can already start with another job. Thus when the transportation times are included in the repair times, the results of the model are more negative than the real situation.

The transportation times could also be included in the time of use. This results in the opposite of adding the transportation time to the repair time. The results are more positive than in reality.

If the Armed Forces can provide information about repair times, they can usually only provide average repair times. What exactly is included in this time is not known. It is assumed that the average repair time is the time that elapses between the moment the failed items leaves the building until the time that it returns. This should mean that the data provided already includes the transportation time from and to the repair facilities. The results of the application of the model are in this situation worse than in reality.

ad 2; *Transport times which arise from "borrow activities*".
To consider this type of transportation, in the consolidated situation, the expected borrow activities must be known. This is a complex parameter to establish because of the enormous number of unknown parameters which influence the expected borrow activities. In this stage of the project, where the current policies and scenario's are not known, and also the exact future policies are not known yet, a calculation of the expected borrow activities would make no sense, because of the high work load involved. But this is no reason to neglect the transport times as results of BA's.

The duration of transportation times, as a result of borrow activities, are not known. But from experiences gained in the organisation, the transportation times between countries are estimated as two weeks. This figure includes all the additional delay such as e.g. extra handling and customer formalities.

For borrow activities, two extreme situations exist.

1. The demand figures are exactly the expected figure, no borrow activities occur.
2. The demand figure is entirely different than the expected one, and for approximately each item, a borrow activity is performed.

When the model is applied, both situation will be calculated. Both situations are rough approximations, and influence the system in a negative way. The first situation is as discussed above. In the second situation, the two weeks transportation time will be added to the repair time. This means two negative effects in the calculation. One because during the assumed transportation time, the repair server will still be busy, but in reality the server could already continue with the next repair task. And a second one, because we assume that each item is obtained by a borrow activity.

The two results are both worse case results. The second one is the worst case situation. Valid conclusions for a particular item can not be drawn with this method. Conclusions about the influence of additional transportation times can be drawn. Also conclusions about the motivation to consolidate or not repairable items, can be drawn.

6.8 Review model

The model discussed, is independent of the policies and approaches used in the participating Armed Forces. This is done because of the variety of meanings for same expression in the several Armed Forces. If the policies etc., operating within the Armed Forces would have been known, it would still have been difficult to translate these policies into definitions so that the systems could be compared with each other or with a consolidated model. Thus an approach is chosen which is independent of the current policies used in the individual Armed Forces.

Not many parameters need be known, to get an impression if consolidation would be wise. But the more parameters that are known, and the more that is known concerning what the parameters actually mean, the more valid would be the results obtained.

The models discussed in Chapter 5 and 6 must be applied as a combination. Because a consolidation of a repair loop, results in less items in the loop, which results in decreasing of total turnaround items. Thus stock levels decrease, which results in decreasing stock costs. But transportation costs etc. will increase. An interface between the two models is desirable in order to obtain the best results.

Chapter 7

Evaluation of the model

7.1 Introduction

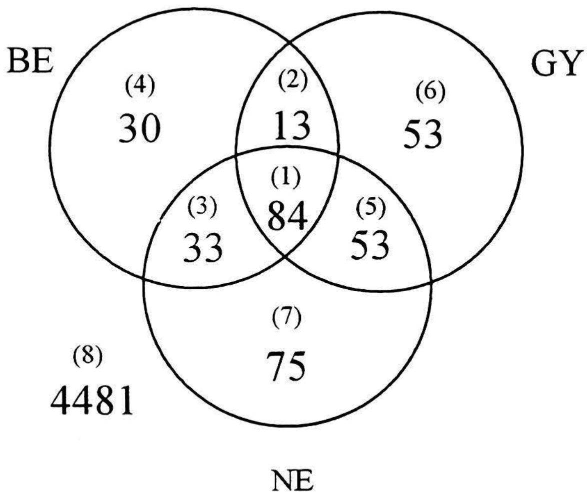
The two models introduced in Chapters 5 and 6 are applied in this chapter. The first paragraph handles the subject of items which are selected for further research. In paragraphs 7.3 and 7.4 the results of the several steps in the models are discussed. This chapter will finish with a review of the data provided by the AF's and the utility of the models.

7.2 Items selection

After the decision to concentrate on the AF's of BE, GY and the NE, the data provided by these AF's, comprising of the study sample of 5,120 items, are filtered out of the database of common items between BE, DK, GY, NE and NO.

Figure 7.1 below, illustrates the situation concerning the items which are considered as repairable items in at least one Armed Force, on a national level. For example group (4), 30 items are considered as repairable in Belgium, but consumable in Germany and the Netherlands. In Belgium, Germany and the Netherlands there are 84 common *"common"* repairable items.

The total stock values in the three Armed Forces for the groups (1) to (8) are given in the table in figure 7.1. These values are based on the data provided by the Armed Forces. The values and percentages do not agree with the values and percentages provided earlier, because in this data, DK and NO are excluded.



group	stock value (US $)	percentage
(1)	68 461 088.38	28.45
(2)	4 667 986.05	1.94
(3)	6 997 362.46	2.91
(4)	6 365 276.61	2.65
(5)	9 184 780.33	3.82
(6)	14 101 670.48	5.86
(7)	8 658 381.65	3.60
(8)	122 203 004.49	50.78
Total	**240 639 550.45**	**100**

Remarks
- Total number of items is not equal to 5,120 because of the incompleteness of some data.
- The numbers in the sections agree with the number of NSN's, which are repairable in the related armies. For example, in group (2), the 13 means that 13 items are considered as repairable in BE and GY, but consumable in NE.

Figure 7.1 The situation of the common *"common"* repairable items.

More detailed data is required for an accurate study concerning the repairable items situation. Notwithstanding that the items in group (1) represent the highest percentage, it was decided to conduct further research in all the groups. The reason for this is that, it is expected that in the groups where an item is considered as an RI in one AF, and as a CI in another, AF money can be saved with small, or even no investment.

The data collection for RI's must be done manually. For this reason, only a small sample, 24 items, were selected out the 341 possible items. The 24 items were not randomly selected. First the items with the highest current stock value in each group were selected. Then a selection based on demand data was made. In total 24 items were selected, of which 5 items belong to group (1) and from the other groups (2) to (7), three items were selected (18 items).

The item information requested from the AF's , was the data needed to apply the models as discussed in Chapter 5 and 6. Some additional data, like source of Repair, and what were the criteria for an item to be considered repairable or consumable, were also asked.

A description of the selected items is included in Appendix VI. The Group Classes (GRCL) and the Material Groups (MG) are explained as well. An overview of the data send in by the AF's is enclosed in Appendix VII.

7.3 Consumable or Repairable

In this paragraph, the 'decision model' as to whether an item may be considered as a repairable or as a consumable (Chapter 5) is applied. The model contains three steps:

1. Evaluation of current stock level
2. Comparison of repair and procurement parameters
3. Cost analyses

It must be noted that the data provided by the Armed Forces was disappointing. Questions concerning the 'number of items in use', 'repair prices', 'repair times' etc., were often not answered. If they were answered, the exact meaning was often unclear. Belgium, for example, could not provide data from before the third quarter of 1995. Because of the above reasons, valid conclusion cannot be drawn. Therefore, this paragraph must be seen as a case study. The results are only indications.

7.3.1 Step 1: Evaluation of current stock level

In this step, for each item the Out of Stock Period (OSP) is calculated. The OSP is the time that can be covered with the current (global or local) stock situation, based on average demand. The OSP is calculated for the situation that the item should be globally considered as a consumable item. For this calculation, only the serviceable stock is counted.

The items which were researched, were mainly M-113 and Leopard I/II items. At the present time neither system has been phased out. The start of a *phase out* period is also not known. For this reason, the OSP's cannot be compared to the expected remaining life time. Therefore, the policies, as stated in paragraph 5.3.1, are used. If the stock position is enough to cover 10 years or more, the item will be considered as a *consumable item*. If the stock position is between 5 and 10 years, the item will temporarily[2] be considered as a *consumable item*. If the stock level is below 5 years, the item will be researched in more detail as explained in the next steps.

Enormously high stock levels are often a result of a decrease of systems in use. For example, it has been decided to decrease the number of Leopard tanks in the armies. This resulted in a return of Leopard items, which could explain the high current stock situation of Leopard items. Because the decision to decrease the number of complete Leopard Weapon Systems is a firm decision, the stock levels of Leopard items may be reduced.

From the 24 selected items, 8 items are in such a stock position that more than 10 years can be covered with the current stock level if the item is considered as a consumable item. These items will be considered as consumable items.

Three items out of the 24, have enough stock to cover between 5 and 10 years demand. These items could be temporary considered as consumable items.

The remaining 13 items, the items with a global stock level between 0 and 5 years, will be researched in more detail. The results are summarised in table 7.1.

Table 7.1: Results step 1: Evaluation of current stock level

Out of Stock Period in years	# NSN
0 - 1	2
1 - 2	5
2 - 5	6
5 - 10	3
> 10	8

Items with global stock position greater than 10 years;

- The global stock value of the items which have a stock level greater than ten years is \$ 5,370,249.28 (US). The global annual demand for these items has a value of \$ 153,641.33. These values are calculated by considering the individual Armed Forces prices. From these values it may be concluded that a lot of money is invested in nearly dead stock. This confirms the results of earlier studies concerning SHARE and COMMIT (Oorebeek July 1997).
- The advantage of considering these items as *consumable* instead of *repairable*, is not reduced cash flow demand, but the decrease of the stock levels.
- What was striking, was the fact that, in the AF's which considered the items as RI's, the Procurement Lead Time (PLT) was much longer than the average PLT for the AF's. This is probably due to the fact the items were still considered as RI's.

[2] Temporary can mean:
- failed items will be kept in unserviceable stock
- item is considered as a CI, until the stock level has reached an established required level

Items with global stock position between 5 and 10 year;

- The global stock value of the items which have a stock level of between 5 and 10 years is $1,523,314.91 (US). The global annual demand for these items has a value of $ 240 850.33 (US). These values are calculated by considering the individual prices. For these items, a more detailed research, whether, and in which manner, the item will temporary be considered as a *consumable* item, is recommended. *Temporary consumable* could mean the failed items will be kept as unserviceable until they are needed and will be repaired. *Temporary consumable* can also mean that the failed items are scrapped until a certain stock level is reached. The overall goal being to decrease the stock level.

An item by item review of this step is enclosed in Appendix IIX.

The model will continue with the remaining 13 items.

7.3.2 Step 2: Comparison of the repair and procurement parameters

In this step, for each remaining item out of step 1, the ratio's concerning the repair and procurement parameters were calculated. These ratio's are the Procurement Price divided by the Average Repair Costs (PP/ARC) and the Procurement Lead Time divided by the Average Repair Time (PLT/ART).

The German army could only provide the average repair costs during the life time of the item. For NSN's where the scrap rate was known, the expected times during which the item can be used (or repaired) is calculated. The repair cost given by Germany, divided by this result gives an estimation of the average repair price per repaired item.

For two items, a decision could be taken because of the extreme values of the ratio's. One NSN (No. 121771825), currently repairable in BE and GY, will be considered as repairable because of the high value of the ratio's. The ratio PP/ARC is equal to 3.51 and the ratio PLT/ARC is equal to 3.80. Both ratio's are based on the GY data.

A second NSN (No. 009999842) will be considered as consumable. This item was repairable in BE and consumable in GY and NE. Therefore, only data from BE is available concerning the repair parameters. The repair price is about five times the procurement price. The PLT/ART is, based on the BE Procurement Lead Time, equal to 1.68. This value is not extremely low, but if we consider the PLT from NE, 30 weeks, this ratio will decrease to 0.73. This should result in the decision to consider the item as *consumable*.

Five NSN's will be researched in step 3. And for 6 NSN's it was decided not to do further research. The main reasons for this decision are:

1. The lack of confident data
2. The enormous difference between the provided ARC's. This difference may be an indication that the repair task are not comparable with each other.

An item by item review of this step in enclosed in Appendix IIX.

7.3.3 Step 3: Cost analysis

Five NSN's are remaining for this step. A detailed cost comparison cannot be done because only average repairable costs are known. The simple cost comparison is done, which results in the difference in costs if an NSN's is considered repairable or consumable, expressed in the number of replacements. The difference in costs are calculated by (Ref. : § 5.3.3 Step 3: Cost analysis):

$$E_{cons}(Cost) - E_{rep}(Cost) = Q \cdot (P_{proc.} - P_{rep.}) \cdot (1-s)$$

Three out of the five NSN's are already considered as repairable in the three armies. An example is given in Table 7.2 of the calculation for NSN No. 121675887, a track shoe. This item is already considered as repairable in the three Armed Forces.

Table 7.2: Data concerning NSN 121675887

NSN: No. 121675887	BE	GY	NE
Procurement Price (US $)	355.14	335.33	400.00
Average Repair Cost (US $)	178.38	199.03	?
Scrap rate (%)	0	80	?
Yearly Replacements (#)	6,968	32,725	0

This NSN is considered as a repairable item in BE, GY and NE. The difference in costs, based on whether the item is considered to be consumable or repairable, in relation to the number of replacements is drawn in figure 7.1.

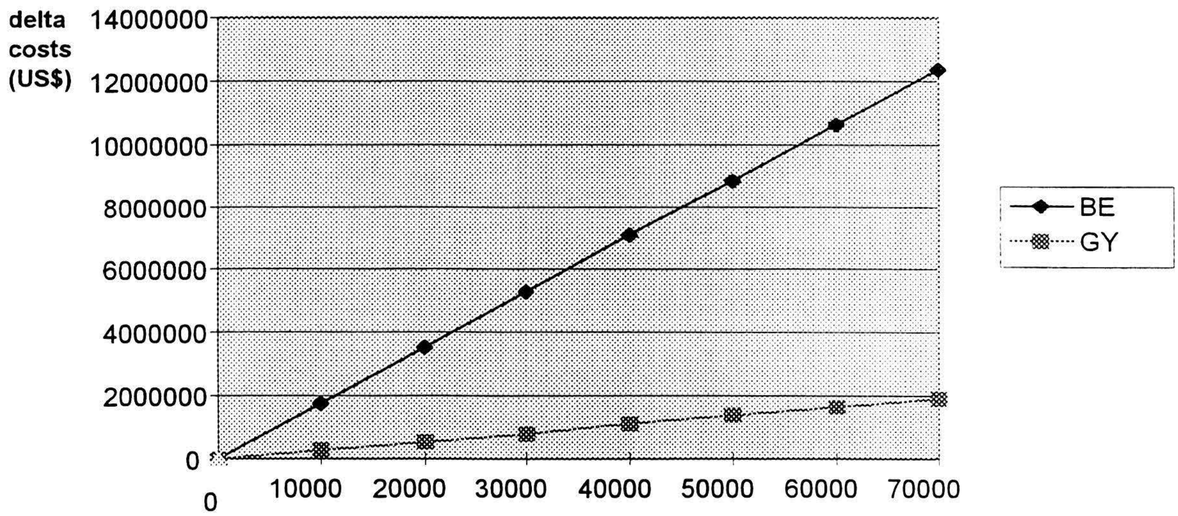


Figure 7.1: The difference in costs if an item is considered as consumable or repairable

The cost difference, depending on whether the item is considered as a repairable or as a consumable, in a consolidated situation, based on the BE data is 7 million US $. The same calculation, but based on the GY data, brings a cost difference of 1 million US $. The cause of the difference of 6 million US $ is mainly due to the high scrap rate given by GY. But here again we have to be careful not to draw conclusions, because we don't know the capability of the repair facilities. It could well be that GY has a high scrap rate because there is not more repair capacity available to repair more items. Currently, BE has a scrap rate equal to 0, thus the number of replacements is equal to the number of items that are repaired. In a consolidated situation the number of replacements, and thus also for the number of items that must be repaired, if the scrap rate is kept to 0, is more than 5 times the current number of replacements. This could well mean that the repair facilities must be expanded, this in turn results in an investment and thus an increase in repair costs. But here it must be noted that it is unknown if the items are repaired by the BE Armed Force themselves, or by a contractor.

For the other 4 NSN's out of the remaining 5 NSN's, the results are enclosed in Appendix X .

No information is available about repair capabilities, or the cost of expanding the repair facilities, etc. Without more information it cannot be decided whether the NSN must be considered as a CI or an RI.

7.4 Review decision model

Step 1:
After applying the first step of the decision model, 8 NSN's, out of the 24 NSN's, can be considered as *consumable* because of their enormous global stock level. Three NSN's can be considered as *temporary consumable*, because their global stock levels are sufficient to cover five to ten year the average demand. The results of this step are shown in table 7.3 below. The first four columns show whether the NSN is currently repairable or not. The last column shows the results of this step.

Table 7.3: Results step 1 decision model.

NSN Number	BE	GY	NE	new
001359035	Y	Y	Y	N
121428750	Y	N	Y	N
121469610	Y	N	N	N
121463685	N	Y	Y	N
999604296	N	Y	Y	N
121873068	N	Y	N	N
121431077	N	N	Y	N
121428179	N	N	Y	N
121405395	Y	Y	N	temp. N
005370372	Y	N	Y	temp. N
121455960	N	Y	N	temp. N

Y = repairable N = consumable

The first step in this decision model is a useful step. It appears that, based on the serviceable stock position, more than 30 % of the items can be considered as consumable in a consolidated situation.

Step 2:
Within this study, this step cannot be performed as it should. Out of the remaining 13 items, only for two items could a decision be taken. Namely one repairable and one consumable. And even for these NSN's, estimations are done for certain values. The result did not meet the expectations.

Several aspects are the cause, namely:

- If an NSN is considered as a consumable item in one of the Armed Forces , no repair parameters are available in that Armed Force in case the item should be repairable. It was planned to use the values from the Armed Forces where the NSN was already repairable. This finally was not done, as the differences in those values between the Armed Forces, for NSN's where more Armed Forces have data available for certain (repairable) NSN's, are too important Estimations for those values will not have resulted in valid figures.
- A lot of data is missing. If an NSN is considered as a repairable, all the other four parameters are often not given. Besides this, average repair prices and time equal to zero occur.
- It is only possible to compare parameters if their meaning is equal. As long it is not known what is included in the repair prices and times, this step may not be done.
- The type of repair must be equal. One cause of the big difference in the values of the repair parameters could be that the type of repair is not equal on the national level.

As long as the provided data is not reliable, it is not sure that the repair tasks are equal. This, combined with the point that the exact meaning of the parameters are not known, means that this step is not useful. This step could only be useful to show the relations between procurement, repair times and prices. Even so, if all parameters are known, this step can be used to show extreme situations.

Table 7.4: Results step 2 decision model.

NSN Number	BE	GY	NE	result
121771825	Y	Y	N	Y
009999842	Y	Y	N	N

Y = repairable N = consumable

Step 3.
Only a simple cost comparison could be performed for the selected items. Without information about repair facilities, no decision can be made. The enormous difference in the several parameters is again, clearly out of this step.

General overview
Only the first step of this model can be performed correctly. The two other steps are too detailed. at this stage of COMMIT. Even in a later stage the model will probably not be as applicable as it is wished, because theory and practice will never be equal. One other reason to go through the main aspects of a model like this, is to form an impression about the several decision criteria, the influence parameters and existing problems. This scope is achieved.

7.5 Turnaround model

By the application of the decision model (Ref. §7.3), one NSN is considered as repairable. This decision is based on the German data concerning prices and lead-times. The next step for this item

(NSN Number 121771825) should be to apply the model discussed in Chapter 6. Not one AF was able to give accurate information as to how much this item is in use. (see Appendix VII). Because of this, it is impossible to apply the turnaround model for the item. If one of the AF's would have known the number of items in use, the total NIU could have been estimated.

The remaining five items in step 3 (Ref. § 7.3), will be used to show the principals of the turnaround model. For these items it was not possible yet to decide whether they will be considered as a RI or a CI.

NSN: 121675887

For BE and GY, the number of items in use is not known. NE knows the number of items in use, but not if any replacement took place during the last 8 quarters. Thus a Mean Time To Replace cannot be calculated from this data. Because of this, an estimation of the number of items in use in BE and GY is also not possible.

Conclusion: Not enough information provided to apply the turnaround model.

NSN: 121430186

BE: No replacement in the last 5 quarters.

GY: The number of items in use is estimated by use of the Dutch data. If the maximum number of items that could be repaired in one time unit (10/29=0.345 item per week) is compared with the maximum number of items that could fail ($3790 \cdot 0.99/1331=2.85$ items per week) in one time unit, it can be concluded that a satisfactory service level, in the steady state situation, will never be achieved. It is possible that 'the number of items in use' is decreasing and therefore not all the items will be repaired.

NE: The data shows a queue (number of items in unserviceable stock) for the repair server, while zero items are in repair. This could be explained if the item is temporary considered as a consumable item, and the failed items will be kept in unserviceable stock until they must be repaired because they are needed in serviceable stock. In this situation the model cannot be applied, in a steady state situation all the items are waiting for repair because there is no repair server.

Conclusion: If the turnaround algorithm is applied, a satisfactory service rate will never be achieved. This applies equally for individual situations as well as the consolidated situation. Adding more items in the repair loop will improve the service rate temporary, but will not improve the service rate in the 'steady state' situation.

NSN 121456305

The 'Mean Time To Replacement' is calculated from the Dutch data and is equal to 555 weeks. From this result, the number of items in use in BE and GY are estimated.

BE: The service rate can be influenced by the number of turnaround item. This is because the maximum number of items that can be repaired is higher than the maximum number of items that fail.

NE: As NSN (No. 121456305) discussed before. In NE, no items were in repair, but 9 items were waiting for repair. An individual turnaround calculation can not be performed for NE, an infinite number of turnaround items is needed in NE to achieve a satisfactory service rate.

GY: An infinite number of items is needed to achieve a satisfactory service rate in the steady state situation.

For BE the number of turnaround items (K) to achieve a service rate of 70%, 80% and 90% is calculated. These figures are also calculated if the number of replacements and the number of items in repair are consolidated over BE and NE. For this calculation, the values of the BE army are used. The consolidated calculations are restricted to BE and NE because of the limits of Excel v5.0. The consolidated situation is calculated twice. Once if no additional transport time because of borrow activities is considered, and secondly if all the items are obtained by one borrow activity. The results are shown in table 7.5 below. In the last table, the current number of turnaround items are given. These numbers are the sum of the number of items in use, waiting for repair, in repair and serviceable stock.

Table 7.5: The number of turnaround items (K) needed to achieve certain service rates.

	70%	80%	90%	current K
BE	78	78	79	141
NE	∞	∞	∞	277
Total individual	∞	∞	∞	-
Consolidated (BE)	240	240	241	418
Consolidated (BE) included transport	240	241	242	-

As can be seen, with one more item in the loop the service rate increases enormously. This is because the maximum items that fail in a time unit is much smaller than the maximum number of items that can be repaired in one time unit. Or in formula:

$$\text{if} \quad \frac{m(1-s)}{MTTR} <<< \frac{n}{ART},$$

the service level will increase enormous by adding one item in the turnaround loop.

In this situation: $\frac{m(1-s)}{MTTR} = \frac{237 \cdot (1-0.55)}{555} = 0.1922 \qquad \frac{n}{ART} = \frac{17}{12} = 1.4267$

For this item, adding two weeks to the repair time, to cover the transport times, does not have significant influence. This is also because of the reason explained above.

NSN 12145594

For this NSN, none of the Armed Forces had available data concerning the number of items in use. Calculations can not be performed.

NSN 121719741

For this NSN, none of the Armed Forces had available data concerning the number of items in use. Calculations can not be performed.

7.6 Review turnaround model

For only one NSN out of these 6, could the turnaround model be applied. This result does not meet the expectations for several reasons, namely:

- Many parameters which are needed to apply the model can often not be provided. The parameter "number of items in use" is the most difficult parameter to provide.
- In all cases where sufficient parameters were provided it occurred that no satisfactory results were obtained. For example no replacements took place over the researched period. Or the repair times were so long that only temporary improvement of the service rate could be achieved; that means in the steady state situation, an infinite number of turnaround items is needed.
- It was assumed that the number of repair servers is equal to the number of items in repair as long as items are waiting for repair. This seems not to be correct. Often, items are waiting for repair but no items are in repair.
- Even if the probabilities were calculated with the use of the re-current relation, the limits of Excel v5.0 were reached. Because it took the Armed Forces more time to collect the data than was expected, there was no time left to do the calculation in another way.

Notwithstanding that the model could not be applied with practical data, the following facts became obvious:

- A satisfactory service rate can only be achieved if the average number of failed items per time unit is about (equal), or less than, the maximum number of items that can be repaired in that time unit ($\frac{m(1-s)}{MTTR} \leq \frac{n}{ART}$

  where: m = number of items in use
  s = scrap rate;
  n = number repair servers;
  $MTTR$ = Mean Time To Replacement
  ART = Average Repair Time).

- If $\frac{m(1-s)}{MTTR}$ is much smaller than $\frac{n}{ART}$, the service level will increase enormous by adding one item in the turnaround loop. The larger the difference in this direction is, the more the service level will increase by adding one item.

- The closer $\frac{m(1-s)}{MTTR}$ is to $\frac{n}{ART}$, the more impact a consolidation of the repair loops has.

If the correct data is available, the turnaround model can be used to research whether consolidation makes sense or not. But the correct data is difficult to obtain. To receive exact data, detailed information about the operational concepts, the maintenance concepts, the background of the current method of managing the repairable item etc. must be known. To clarify this, each item must be researched separately in detail, and within each Armed Force, and also the repair facilities must be considered. Thus the general conclusion is that the turnaround model is theoretically justified but practically difficult to apply.

Chapter 8

Conclusion and Recommendations

8.1 Introduction

In this chapter, the conclusion and recommendations resulting from the performance of the final assignment are described. The final assignment was formulated as:

> *"Develop and evaluate models which support the decision whether an item will be considered repairable or consumable. and, if the item is considered as repairable, in which situations is consolidation of repairable items advisable?"*

Each model, and each step in the model is described briefly and evaluated. The evaluation is done with 24 items selected out of the first study sample of 5,120 common items between the armies of Belgium (BE), Denmark (DK), Germany (GY), Netherlands (NE) and Norway (NO). For the evaluation of the models, the data collection is limited to the armies of BE, GY and NE. In the paragraph 8.5, some recommendations are presented for a potential continuation of this study.

8.2 Conclusions concerning decision model: repairable or not.

Step 1: Evaluation of the current global stock level
In this step the Out of Stock Period (OSP) is calculated if the item is considered as consumable. This OSP is compared to the remaining expected life time of the system. The remaining life time of a system is almost never the same for all Armed Forces. Besides this, the remaining life time is almost never known in the individual Armed Forces and very difficult to estimate. For this reason limits are set in connection with policies used within NAMSA. If the global OSP is longer than 10 years, the item will be considered as CI. If the OSP period is between 5 and 10 years, the item will temporarily be considered as CI. Items with an OSP of less than 5 years must be researched in more detail before a decision can be taken.

After applying this step, 8 NSN's out of the 24 NSN's, can be considered as consumable because of their enormous global stock level. Three NSN's can be considered as temporary consumable, also because of their global stock levels, which are sufficient to cover five to ten years of the average demand.

The first step in this decision model is obviously useful step. Because it can be demonstrated that, based on the serviceable stock position, more than 30 % of the selected items can be considered as consumable in a consolidated situation.

Step 2: Comparison of repair and procurement parameters
The second step in the model, procurement lead times (PLT), average repair times (ART), procurement prices (PP) and average repair prices (ARP) are related to each other. This step is included in the decision model because it may happen that long PLT make it necessary that an item is considered repairable, even if the ARP was several times higher than the PP.

Within this study, this step was not performed as it should have been. Out of the remaining 13 items, only for two items could a decision be taken. Namely one repairable and one consumable. And even for these NSN's, estimations are done for certain values. For six items it was decided to exclude these from further research, because of unreliable data. Therefor, the result of this step did not meet the expectations.

Several aspects are the cause of this, namely:

- If an NSN is considered as a consumable item in one of the Armed Forces, no repair parameters are available in that Armed Force in cases where the item should become repairable. It was planned to use the values from the Armed Forces were the NSN was already repairable. This was not done as, the values were often not provided and if they were provided, the differences in these values between the Armed Forces (for NSN's where more Armed Forces had data available for certain repairable NSN's), were to important. Estimation from these values could not result in valid values.
- Much of the required data is missing. If an NSN is considered as repairable, all the four parameters are often not provided. Besides this, average repair prices and time equal to zero occur.
- It is only allowed to compare parameters if their meaning is identical. As long it is not known what exactly is included in the repair prices and times, this step is not worthwhile be done.
- The type of repair must be equal. One cause of the large differences in the values of the repair parameters could be that the type of repair is not equal on a national level.

As the provided data is not complete and often it seemed not reliable, one can not say that the repair tasks are equal. This in combination with the fact that the exact meaning of the parameters is known, this step is considered not to be useful, it could only be useful to show the relations between procurement and repair times and prices. Once all parameters are known, extreme situations can be shown.

Step 3: Cost analyses.
The last step in the model is a cost comparison. All costs which arise during the life time of an item must be considered. Two cost comparisons are discussed. One simple model where the difference in costs, (between the item as repairable or as consumable), is expressed in the demand (or number of replacements). The second comparison is based on the Life Cycle Cost Analysis. This is a systematic analytical process of evaluating various alternative courses of action, with the objective of choosing the best solution.

The aim of this cost discussion is to provide insight into which costs categories increase or decrease per item by using the different stock management systems. Five stock management systems are considered; consumable consolidated, repairable individual self, repairable individual contractor, repairable consolidated self and repairable consolidated contractor.

The general impression is an increasing of costs if the item is considered as repairable item. This is a logic result, because all the costs during the life-cycle of the item are considered. This result must be combined with the number of replacements and the scrap rate, or the expected time that an item can be used.

Only a simple cost comparison could be performed for the selected items. Without information about repair facilities, no decision can be made. The enormous difference in the values for the parameters seems again clear out of this step.

8.3 Conclusions concerning Turnaround model: Consolidate repairable items or not

The turnaround model is aimed to calculate the number of turnaround items needed in a repair loop to achieve a certain service level. This model is based on a combination of the classical queuing theory and a Markov routing. The repairable loop is modelled as a closed system with two multi-server stations and a fixed number of items in the system. The multi-server stations are one *"usage station"* which models the usage process, and one *"repair station"* which models the repair process. The quantity of items in use is equal to the number of *"usage servers"*. The quantity of items that can be repaired the same time is equal to the number of *"repair servers"*. The total number of items needed to achieve a certain service level is calculated for each individual Armed Force and for one consolidated situation. The sum of all items needed in the individual Armed Forces is compared to the consolidated situation. If the number of items needed in the consolidated repair loop is less than the sum of the individual repair loops, for an equal service level, consolidation makes sense.

Only for one NSN was it decided to consider it a repairable. For five items, no decision could be made in step 3 of the decision model. These remaining 6 NSN's are used to evaluate the turnaround model.

For only one NSN out of these 6, the turnaround model could be applied. This result does not meet the expectations because of several reasons, namely:

- Many parameters which are needed to apply the model can often not be provided. The parameter "number of items in use" is the most difficult parameter to obtain.
- In all cases where sufficient parameters were provided it occurred that no satisfactory results were obtained. For example no replacements took place over the researched period. Or the repair times were so long that only temporary improvement of the service rate could be achieved; that means in the steady state situation, an infinite number of turnaround items is needed.
- It was assumed that the number of repair servers is equal to the number of items in repair as long as items are waiting for repair. In reality this seems not to be so as items often are waiting for repair but no items are in repair.
- The time frame during which the AF's should have provided their data was not respected so data was received very late. For calculations of the number of turnaround items, Excel v5.0 was chosen, unfortunately it was found that the limits of Excel were reached when the probabilities were calculated. Also if the probabilities were calculated by the use of the recurrent relation between the probabilities, the limits were reached. Due to time constraints, it was not possible to evaluate and make use of other possibilities for accomplishing the necessary calculations.

Notwithstanding that the model could not be applied with practical data, the following facts became obvious:

- A satisfactory service rate can only be achieved if the average number of failed items per time unit is about (equal), or less than, the maximum number of items that can be repaired in a that time unit ($\frac{m(1-s)}{MTTR} \leq \frac{n}{ART}$

where: m = number of items in use
s = scrap rate;
n = number repair servers;
$MTTR$ = Mean Time To Replacement
ART = Average Repair Time).

- If $\frac{m(1-s)}{MTTR}$ is much smaller than $\frac{n}{ART}$, the service level will increase enormous by adding one item in the turnaround loop. The larger the difference in this direction is, the more the service level will increase by adding one item.
- The closer $\frac{m(1-s)}{MTTR}$ is to $\frac{n}{ART}$, the more impact a consolidation of the Armed Forces repair loops has.

If the reliable data is available, the turnaround model can be used to research whether consolidation makes sense or not. Correct data is for the time being difficult to obtain. To obtain the required exact data, detailed information about the operational concepts, the maintenance concepts, the background of the current method of managing the repairable item etc. must be known by the Armed Forces. To clarify on this, each item must be researched separately in detail within each Armed Force, and also the repair facilities must be considered. Thus the general conclusion is that the turnaround model is theoretical justified but practically difficult, at least for the time being to apply.

8.4 General remarks

To run the application of the developed model, much detailed data is necessary, as this data was not made available one can say that in this stage of the COMMIT study no reliable figure on possible savings can be achieved. Even an estimation is not opportune because the few provided data was too divergent. The developed models can well be used to provide insight into which parameters do influence the decisions, the values of the impact can be seen as well.

Consolidation will probably have more impact for small Armed Forces than for big Armed Forces. The advantages for big Armed Forces must be evaluated when they are compared to each other.

Some causes for the difficulty to provide the right data by the Armed Forces are apparent, namely:

- In the defence environment, people usually work for not more than three till five years in one position. This means, if one has made a decision, for example that an item is considered repairable, his successor may often not know the cause of this decision.
- It is not known for NAMSA, how the current stock levels are built up. For example Armed Forces rely on allocated budgets and often have budgetary constraints which may have as cause that management's policies cannot be complied with.
- The trend at this moment is a decreasing of the operational size of Armed Forces. This results in the fact that serviceable items are returned to national depots which means a higher excess.

8.5 Recommendations

During this study it became obvious that it is often difficult for the individual Armed Forces to provide information on the logistic parameters they use. Also it became obvious that for the provided data the exact meaning and the source of origin could not well be defined.

Above experience leads to recommend conditions to be complied by the Armed Forces so they can participate in COMMIT. One of the conditions would for example be that they are able to provide sound information on the policies they apply for national level settings

To avoid to be faced with unreliable data, it should be envisaged to recommend to Armed Forces to analyse their available data sources and to compare those by doing an internal feasibility study with the COMMIT requirements.

Because of the enormous amount of parameters which influence the results, on whether consolidation makes sense or not, and also because of the above discussed facts, and the general unreliability of the provided data a comprehensive simulation study is recommended. In this simulation study, the sensitivity of the concept could be researched. Further the impact of, for example, the "Borrow Activities" which come up in a consolidated situation could be made visible..

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Abbreviations

AF	Armed Force
ATOV	Annual Turn Over Value
BA	Borrow Activity
BE	Belgium
BoD	Board of Directors
BOM	Bill of Material
CI	Consumable item
COMMIT	Common Item Material Management System
DK	Denmark
EDP	Electronic Data Processing
EOQ	Economic Order Quantity
GRP	Global re-order point
GY	Germany
LCA	Life Cycle Cost Analysis
LRP	Local re-order point
NAMSA	NATO Maintenance and Supply Agency
NAMSO	NATO Maintenance and Supply Organisation
NASCO	NATO Spares and Cost Optimisation system
NATO	North Atlantic Treaty Organisation
NCD	National Item Category Information, is an item repairable Yes or No
NE	Netherlands
NO	Norway
NSN	NATO Stock Number
PLT	Procurement Lead Time
PROFIT	Provisioning File for Items
QTY	Quantity in stock
R	Review period
RI	Repairable Item
SACEUR	Supreme Allied Commander Europe
SHAPE	Supreme Headquarters Allied Powers Europe
SHARE	Stock Holding and Asset Requirements Exchange
SIC	Statistical Inventory Control
SLO	Stock level operating stock
SLP	Total Quantity in pipeline, in case of repairable item
SLR	Stock level re-order point
SLS	Stock level safety stock
SOS	Source of supply
UOI	Unit of issue
UPR	Unit Price in US
WSP	Weapon system Partnership Committee

APPENDICES

Common Item Material Management

NAMSA

COMMIT

"The theory and practice of consolidated Repairable Item Management in the NATO environment"

NAMSA

Let's keep nations together

NATO MAINTENANCE AND SUPPLY AGENCY
CAPELLEN, G.D. OF LUXEMBOURG

Capellen (L), August 1997

Thesis Report
Claudia Paro
University of Technology Eindhoven
Technology Management

APPENDICES

Thesis report August '97
NATO Maintenance and Supply Agency, Capellen (L)
University of Technology Eindhoven, TUE (NL)

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Contents

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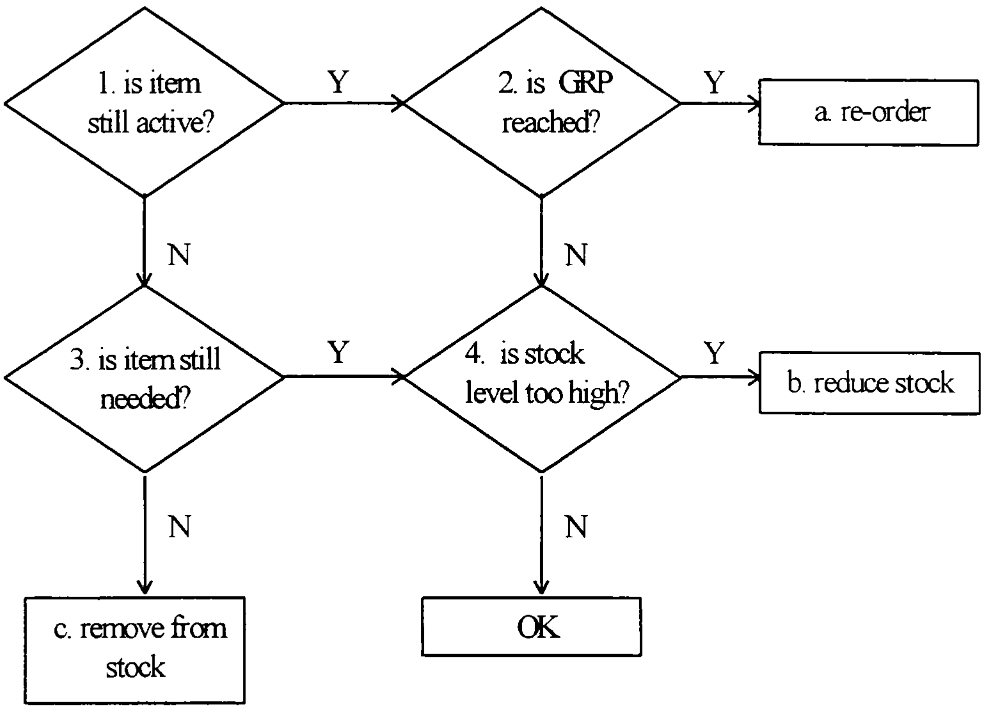
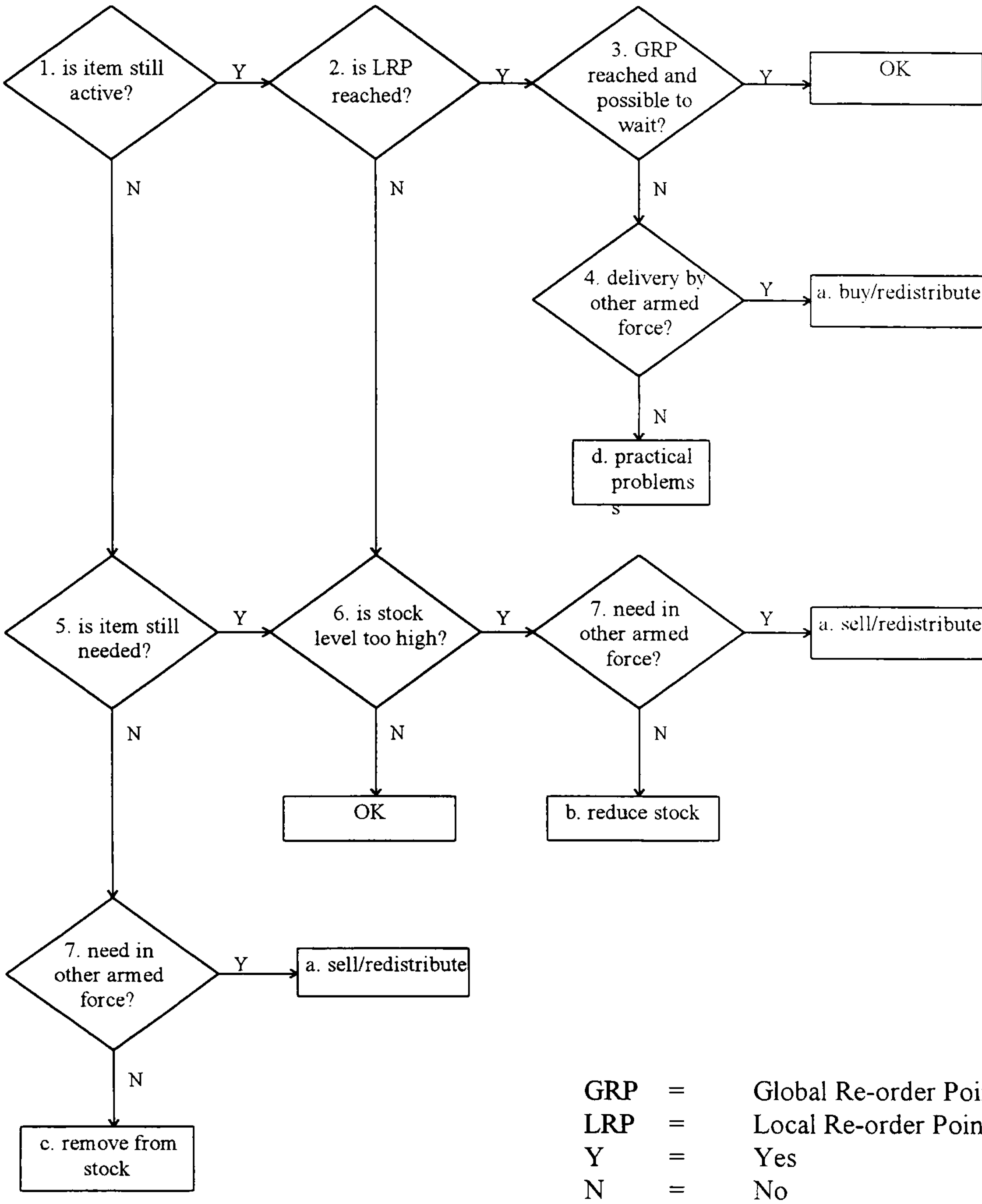
The functionality of the global control system



GRP = Global Re-order Point
Y = Yes
N = No

The functionality of the local control system



GRP = Global Re-order Point
LRP = Local Re-order Point
Y = Yes
N = No

Weapons used in the five participating Armed Forces

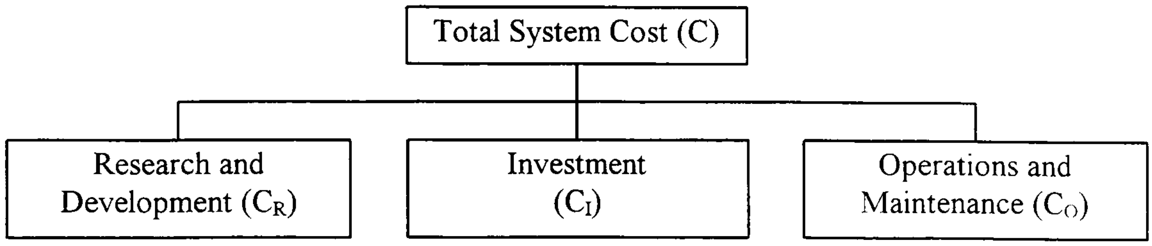
	Leopard	M48A5	M41	Scimitar	M113	Transport Panzer 1	155mm M109 SPH
Belgium	x			x	x		x
Denmark	x		x		x		
Germany	x				x	x	
Netherland	x				x	x	
Norway	x	x			x		
total users	*5*	*1*	*1*	*1*	*5*	*2*	*1*

	155mm M109 A2 SPH	155mm M109 A3 SPH	203mmM110 SPH	M113 TOW TD	107 mm M106 SPM
Belgium	x		x		
Denmark		x		x	
Germany		x			x
Netherland					
Norway		x			
total users	*1*	*3*	*1*	*1*	*1*

	105 mm M101 Howitzer	155mm FH70	203 mm M115 Howitzer	227 mm MLRS
Belgium	x			
Denmark	x		x	
Germany		x		x
Netherland				x
Norway	x			
total users	*3*	*1*	*1*	*2*

Source: **Janes study of common used armour and artillery, based on CD-ROM Jane's Armour and artillery 1995-1996, Study performed by A. Felten, August 1996.**

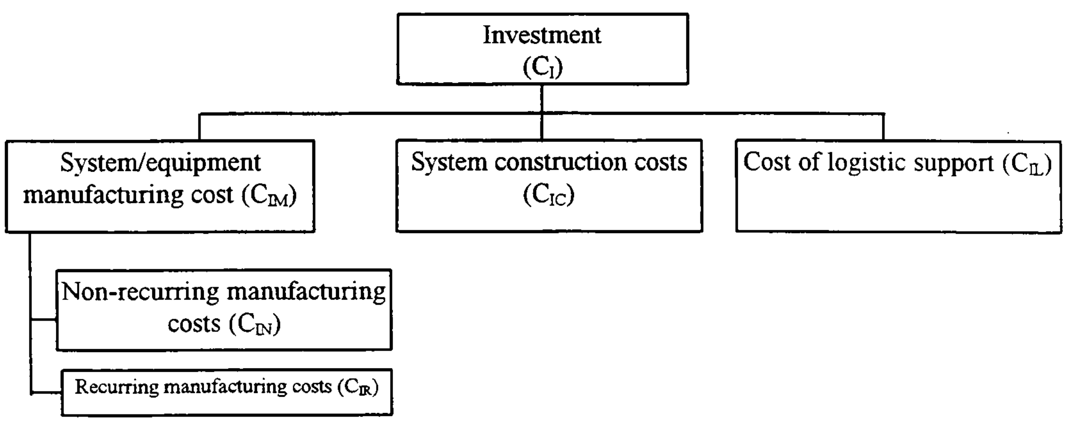
LIFE CYCLE COST ANALYSES, THE INFLUENCE ON THE CONTROL SYSTEMS



Each cost category will be discussed below. The costs categories which are different for the type of control system, tables are shown. These tables show for each type which cost types increase and/or decrease with each control system. In this stage of the project, it is not possible to determine the exact amount of increased or decreased costs. But to get an impression, on each cost category mentioned in the table, a relative weight (<,<<, =, >, >>) is given for each control system. The control system where the cost is in the middle will be rated with =, the one where the cost will be higher with >, much higher >> , lower < and much lower <<. There is chosen for these relative factors because when the costs are for example rated with numbers, the inclination arise to do statistical calculations, what could lead to a wrong image of the situation.

Research and development cost (C_R); Will not be considered.

Investment cost (C_I); Includes all costs associated with the acquisition of systems/equipment (once that design and development has been completed). Specifically this covers manufacturing (recurring and non-recurring), manufacturing management, system construction, and initial logistic support.
Investment costs must be included because the manufacturing costs are part of these cost category. The manufacturing cost could decrease, for example if an item is considered as a RI instead of a CI.



Non-recurring manufacturing costs (C_{IN}):
Includes all fixed non-recurring costs associated with the production and tests of operational systems/equipment's. Specifically, this covers manufacturing management, manufacturing engineering cost, tools and factory test equipment (excluding capital equipment), quality assurance cost, cost of qualification test (C_{INQ}), Cost of production sampling tests (C_{INS}).

These costs could not be influence anymore, thus further consideration of these cost makes no sense.

Recurring manufacturing costs (C_{INP}):
This category includes all recurring production costs as recurring manufacturing engineering support costs (C_{IRE}), production fabrication and assembly labour cost (C_{IRL}), production material and inventory costs (C_{IRM}), inspection and test cost (C_{IRI}), packing and initial transportation cost (C_{IRT}).

	consumable consolidated	**repairable consolidated**		**repairable individual**	
Costs:		contractor	self	contractor	self
C_{IRE}	=	<	<	<	<
C_{IRL}	=	<	<	<	<
C_{IRM}	=	<	<	<	<
C_{IRI}	=	<	<	<	<
C_{IRT}	=	<	<	<	<

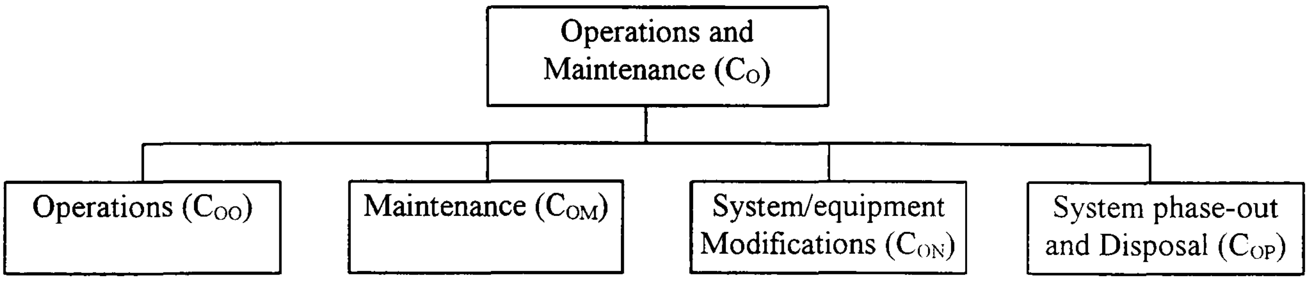
Construction costs (C_{IC}):
Includes all initial acquisition costs as manufacturing facilities cost (C_{ICP}), test facilities costs (C_{ICT}), operational facilities acquisition cost (C_{ICO}) and maintenance facilities acquisition cost (C_{ICM}).

	consumable consolidated	**repairable consolidated**		**repairable individual**	
Costs:		contractor	self	contractor	self
C_{ICP}	>	=	=	<	<
C_{ICT}	=	=	=	<	<
C_{ICO}	=	=	=	=	=
C_{ICM}	=	>	>>	>	>>

Initial Logistic support cost (C_{IL}):
Includes are all integrated logistic support planning and control functions associated with the development of system support requirements, and the transition of such requirements from supplier(s) to the applicable operational site. Included are costs as logistic program management cost (C_{ILM}), cost of provisioning (C_{ILP}), initial spare/repair part material cost (C_{ILS}), initial inventory management cost (C_{ILI}), cost of technical data preparation (C_{ILD}), cost of initial training and training equipment (C_{ILT}), acquisition cost of operational test and support equipment (C_{ILX}), initial transportation and handling cost (C_{ILY}).

Costs:	consumable consolidated	repairable individual contractor	repairable individual self	repairable consolidated contractor	repairable consolidated self
C_{ILM}	=	>	>	>>	>>
C_{ILP}	=	<	<	<<	<<
C_{ILS}	=	=	>	=	>
C_{ILI}	=	>	>	>	>
C_{ILD}	<	=	=	>	>
C_{ILT}	=	>	>>	>	>>
C_{ILX}	=	>	>>	>	>>
C_{ILY}	=	=	=	=	=

Operation and maintenance cost(C_O); Includes all costs associated with the operation and maintenance support of the system throughout its life-cycle subsequent to equipment delivery in the field. Specific categories cover the cost of system operations, maintenance, sustaining logistic support, equipment modifications, and system/equipment phase-out and disposal. Costs are generally determined for each year throughout life cycle.



Operations (C_{OO}):
Includes all costs associated with the actual operation (not maintenance) of the system throughout its life-cycle. Included are the operating personnel cost (C_{OOP}), the cost of operator training (C_{OOT}), costs of operational facilities (C_{OOF}), cost of support and handling equipment (C_{OOE}), this includes the equipment needed for corrective as well for preventive maintenance.

Costs:	consumable consolidated	repairable consolidated contractor	repairable consolidated self	repairable individual contractor	repairable individual self
C_{OOP}	=	=	=	=	=
C_{OOT}	=	=	=	=	=
C_{OOF}	=	=	=	=	=
C_{OOE}	<	>	=	>	=

Maintenance (C_{OM}):
Includes all sustaining maintenance labour (C_{OMM}), spare/repair parts (C_{OMX}), test and support equipment (C_{OMS}),transportation and handling (C_{OMT}), replenishment training(C_{OMP}), support data (C_{OMD}) and facilities (C_{OMF}) necessary to meet the maintenance needs of the prime equipment throughout its life cycle.

	consumable consolidated	**repairable consolidated**		**repairable individual**	
Costs:		contractor	self	contractor	self
C_{OMM}	=	>	>	>	>
C_{OMX}	=	>>	>	>>	>
C_{OMS}	=	>	>	>	>
C_{OMT}	>	>	>	=	=
C_{OMP}	=	>	>>	>	>>
C_{OMD}	=	>	>	>	>
C_{OMF}	=	=	>	=	>

System/equipment Modifications (C_{OM}):
Throughout the system life-cycle after equipment has been delivered in the field, modifications are often proposed and initiated to improve system performance, the MTTR or to make the item more repair friendly. This cost category includes modification kit design (R&D), material, installation and test instructions, personnel and supporting resources for incorporating the modification kit, technical data change documentation, formal training (as required) to cover the new configuration, spares etc. The modification may affect all elements of logistics.

System phase-out and Disposal (C_{OP}):
This category covers the liability or assets incurred when an item is condemned or disposed. This factor is applicable throughout the system/equipment life-cycle when phase-out occurs. This category represents the only element of cost that may turn out to have a negative value, resulting when the reclamation value of the end item is larger than the disposal cost.
The system phase-out and disposal costs includes the negative costs which will be receipt (C_{OPR}) from e.g. a second hand buyer. But nowadays, not only must be paid attention to the paid cost but also to the environmental issues. Thus even disposal cost according the environmental must be paid (C_{OPP}).

	consumable consolidated	**repairable consolidated**		**repairable individual**	
Costs:		contractor	self	contractor	self
C_{OPR}	<	=	=	=	=
C_{OPP}	>>	<	<	<	<

MATHEMATICAL DERIVATION OF THE TURNAROUND MODEL

Because the assumption that the serving times are NE distributed, the condition of the system at moment t is determined by $X(t) = (k_U,k_R)$ with $k_U \geq 0$, $k_R \geq 0$, $k_U + k_R = K$.

where:

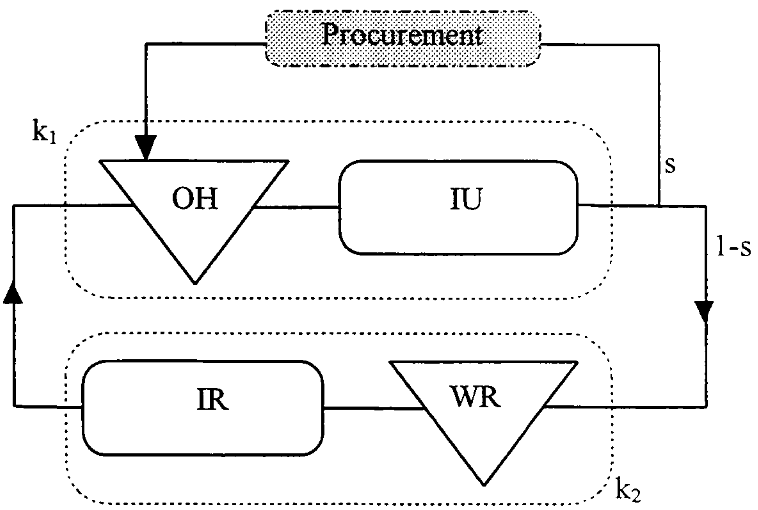
k_U	=	Number of items in use or on hand (OH + IU)
k_R	=	Number of items in repair or waiting for repair (WR + IR)
(k_U,k_R)	=	The event that k_U items are in use or serviceable stock, and k_R items are in repair or unserviceable stock.
K	=	Total turnarounds in the loop, OH + IU + WR + IR

if $k_U + k_R = K$ than $k_R = K - k_U$. In order to keep it more clear, in the rest of this chapter, $k_U = k$, thus $k_R = K - k$ (figure 6.3).

further:

$1/\mu_1$	=	The expected time in use (Mean Time To Replace)
$1/\mu_2$	=	The expected repair time (Average Repair Time)
s	=	Scrap rate, number of scrapped items during a unit of time divided by number of replaced items during that unit of time.
m	=	Number of items in use
n	=	Number of repair facilities

Possible events could be: (0,K) (1,K-1) (2,K-2)............(K-2,2) (K-1,1) (K,0), this means for example the first one (0,K) that 0 items are in use or waiting for use, and K items are in repair or waiting for repair. Thus in this situation, all the items are in repair or waiting for repair.



OH	=	On Hand (Serviceable Stock)	IU	=	In Use
WR	=	Waiting for Repair	IR	=	In Repair

Figure III.1

The repair loop will be modelled as a closed system with two multi server stations. The multi server stations are the usage process and the repair process. If there are 'm' items in use, the station which models the usage process has m servers. If there exist 'n' repair shops, the station which models the repair shop has 'n' servers.

Two models must be derived. One model where more items are in the loop than the sum of the repair useage servers ($m + n < K$). In this model, there are always items waiting for repair (unserviceable stock) and/or waiting for use (serviceable stock). In the second model, there are less or equal items in the loop than the sum of the usage and repair servers ($m < K \leq m + n$). In this model, it may well be possible that there are no items waiting for repair and/or for use.

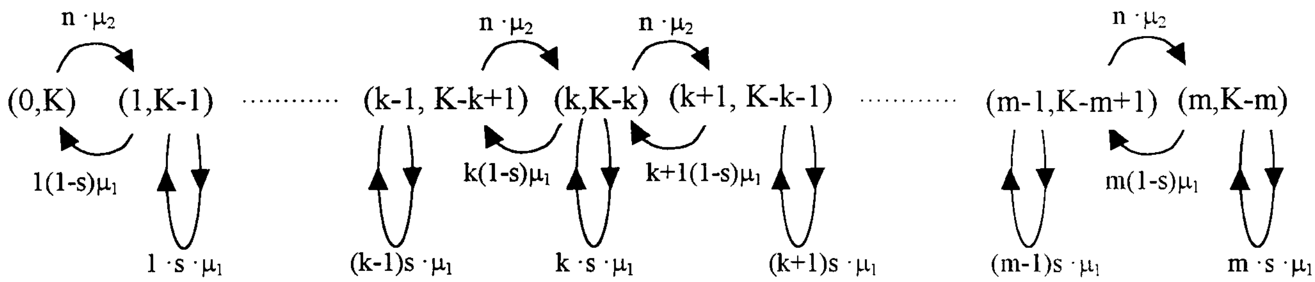
Model 1, $m + n < K$:

step 1: Three situations

Three situations are distinguished in this model.

1. All the repair servers 'n' are busy, there are more items needed in use, $0 \leq k \leq m$
2. All the repair servers 'n' are busy and all the usage servers 'm' are busy, $m+1 \leq k \leq K - n$
3. All the usage servers are busy, but there is free capacity in the repair facility, $K - n + 1 \leq k \leq K$

1. All the repair servers 'n' are busy, there are more items needed for use $0 \leq k \leq m$



Explanation:

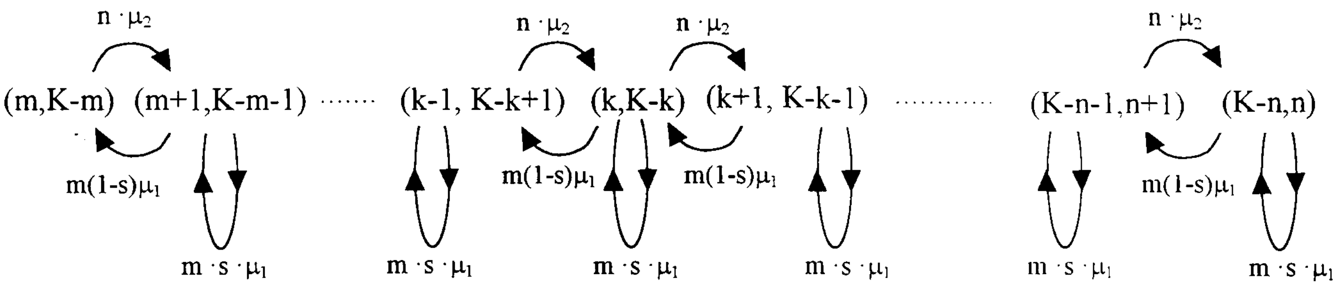
In the first situation (0,K), zero items are in use and K items waiting for repair or in repair. The repair servers have a repair time that is NE distributed with an average repair time $1/\mu_2$. Thus one repair server can repair μ_2 units per time unit. This means, if the system has 'n' repair servers, and all the repair servers are busy, 'n' times μ_2 items could be repaired per time unit. If a real small fraction of time is considered, the probability that at least one item is reade in that time fraction is equal to $n \cdot \mu_2$. The item will leave the repair shop and entres the serviceable stock or directly in use.

The second situation (1,K-1), one item in use and K-1 items in repair. Per time fraction, μ_1 items multiplied by the number of items in use, are expected to fail. But only one item is in use, it is only possible that the item that is in use, fails. When an item fails, the item can be either scrapped, or repaired. When the scrap rate s is the probability that an failed item can not be repaired, $s \cdot \mu_1$ is the probability that in the time fraction considered, one item will be scrapped.

One of the assumptions was: "if an item is scrapped, a brand new item will directly added to the system". Thus an item is scrapped, the system will stay in the same situation. But when the item

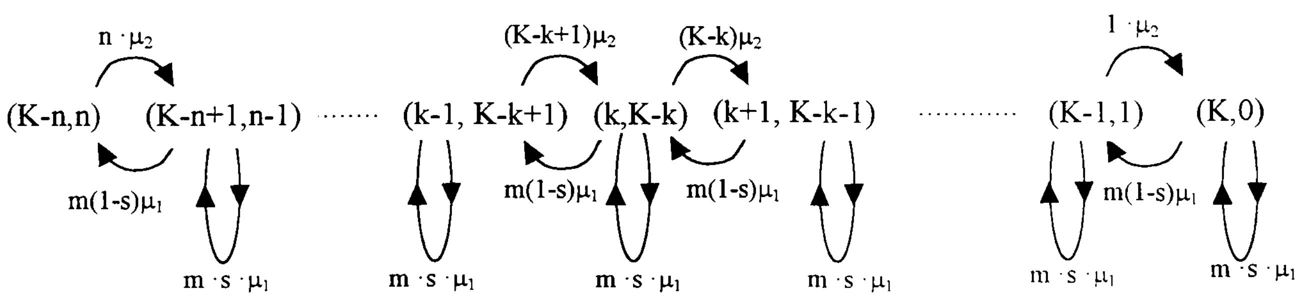
can be repaired, probability is (s-1) $\cdot \mu_1$, the item goes to the repair shop. As soon as there are more items in use (k), the probabilities must be multiplied by the number of items in use.
This part of the system is valid if the items in use is exactly the items needed in use or less. Thus there is no situation where serviceable stock exists.

2. All the repair servers 'n' are busy and all the usage servers 'm' are busy, $m+1 \leq k \leq K-n$



The principal is the same as discussed before. The situations in this part, all the usage servers as well as the repair servers are busy. This means, if the system has 'n' repair servers, and all the repair servers are busy, 'n' times μ_2 items could be repaired per time unit. When we take a real small fraction of time, there is a possibility of $n \cdot \mu_2$ that at least one item is ready in that time fraction, and that item will leave the repair shop to go to the serviceable stock or directly in use. For the items in use, the same explanation is valid. The possibility that one item fails in a fraction of time is $m \cdot \mu_1$.

3. All the usage servers are busy, but there is free capacity in the repair facilities, $K-n+1 \leq k \leq K$



As before, but now there is free capacity in the repair facilities. This means the probability that one item is repaired in a fraction of time, can be calculated by the number of repair server which are busy multiplied by μ_2.

step 2: Calculation of the probabilities:
Because of the fixed number of items in the system, there comes a moment that the system reaches a balanced situation. This balanced situation is called the *"steady-state"* situation. In this situation the probability that k items are in use and K-k items are in repair can be calculated. In mathematical notation: P(k,K-k).

In the *"steady-state"* situation, for each situation the input must be equal to the output. For example situation (k,K-k) in figure III.2 (next page).

Input (k,K-k) = output (k,K-k)

$$P(k-1,K-k+1) \cdot n \cdot \mu_2 + P(k+1,K-k-1) \cdot (1-s) \cdot (k+1) \cdot \mu_1 + P(k,K-k) \cdot s \cdot (k+1) \cdot \mu_1 = P(k,K-k) \cdot \{n \cdot \mu_2 + (1-s) \cdot k \cdot \mu_1 + k \cdot (1-s) \cdot \mu_1\}$$

In this equation can be seen that the loop resulting from the scrapped items, is an input as well as output in a situation. Thus this loop does not influence the calculations of the probabilities. This means, this loop can be ignored in the calculations.

If the *"steady-state"* situation is reached, the input into a situation is equal to the output in a situation, the items moving to the right must be equal to the number of items moving to the left. Thus when we make a cross section *"between two situations"* (figure III.2) the items moving to the left must be equal to the items moving to the right.

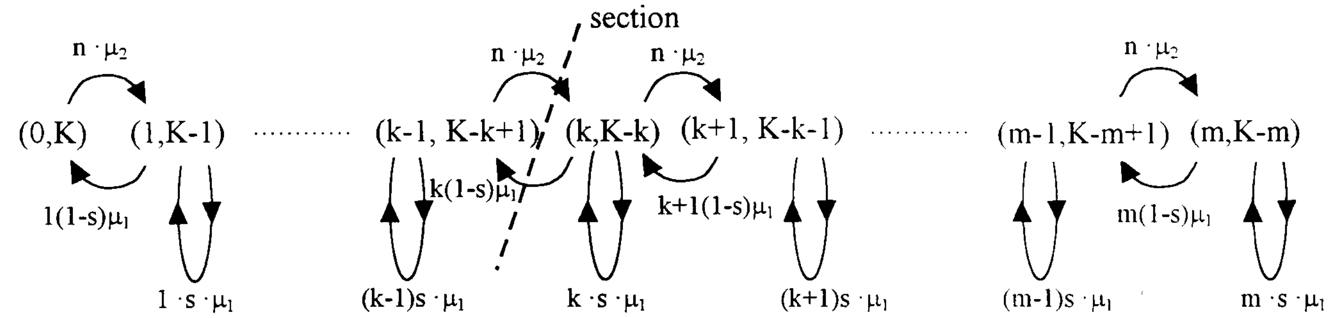


Figure III.2

At the level of the section;

$$P(k,K-k)\ k \cdot (1-s) \cdot \mu_2 = P\ (k-1,K-k+1) \cdot n \cdot \mu_2$$

1. For $0 \leq k \leq m$

$$P(k,K-k) = \frac{n \cdot \mu_2}{k \cdot \mu_1 \cdot (1-s)} \cdot p(k-1,K-k+1)$$

2. For $m+1 \leq k \leq K-n$

$$P(k,K-k) = \frac{n \cdot \mu_2}{m \cdot \mu_1 \cdot (1-s)} \cdot p(k-1,K-k+1)$$

3. For $K-n+1 \leq k \leq K$

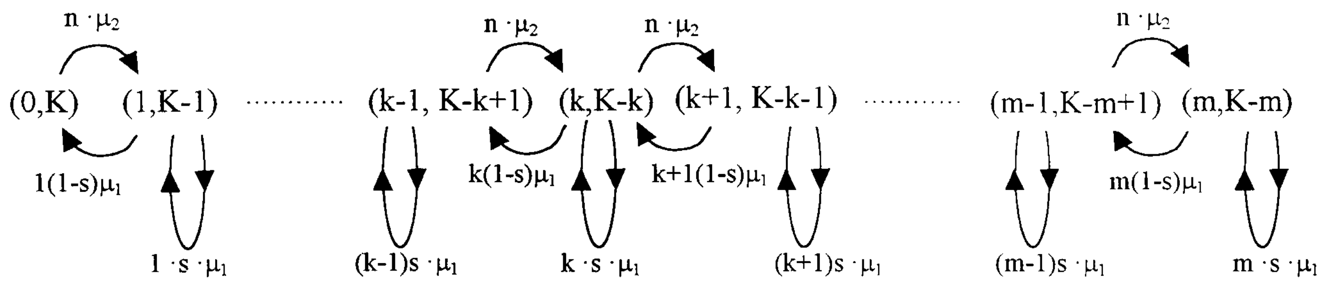
$$P(k,K-k) = \frac{(K-k+1)\mu_2}{m \cdot \mu_1 \cdot (1-s)} \cdot p(k-1,K-k+1)$$

To calculate the probabilities, all the probabilities must be expressed in P(0,K). Second, the sum of the probabilities must be equal to one, and P(0,K) can be calculated. Finally, if P(0,K) is known, all the individual probabilities can be calculated.

Another possibility, to avoid the complex calculations, is the use of the recurrent relations. In each of the general formulas to calculate the probabilities, the formula $P(k)=X \cdot P(k-1)$ can be recognized. This means if one probability is (in first instance) assumed, the relation between all the probabilities can be calculated and equally, as all the probabilities should have been expressed in P(0,K), all probabilities can be calculated.

step 3: Probabilities expressed in P(0,K):

1. *All the repair servers 'n' are busy, there are more items needed in use;* $0 \leq k \leq m$



$$P(k,K-k)=\frac{n\cdot\mu_2}{k\cdot\mu_1\cdot(1-s)}\cdot p(k-1,K-k+1)$$

P(1,K-1);

$$P(1,K-1)=\frac{n\cdot\mu_2}{1\cdot\mu_1\cdot(1-s)}\cdot p(0,K) \qquad \textbf{(A)}$$

P(2,K-2);

$$P(2,K-2)=\frac{n\cdot\mu_2}{2\cdot\mu_1\cdot(1-s)}\cdot p(1,K-1)$$

With equation (A):

$$P(2,K-2)=\frac{n\cdot\mu_2}{2\cdot\mu_1\cdot(1-s)}\cdot\frac{n\cdot\mu_2}{1\cdot\mu_1\cdot(1-s)}\cdot p(0,K)$$

$$P(2,K-2)=\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^2\cdot\frac{n^2}{2!}\cdot p(0,K) \qquad \textbf{(B)}$$

P(3,K-3);

$$P(3,K-3)=\frac{n\cdot\mu_2}{3\cdot\mu_1\cdot(1-s)}\cdot p(2,K-2)$$

With equation (B):

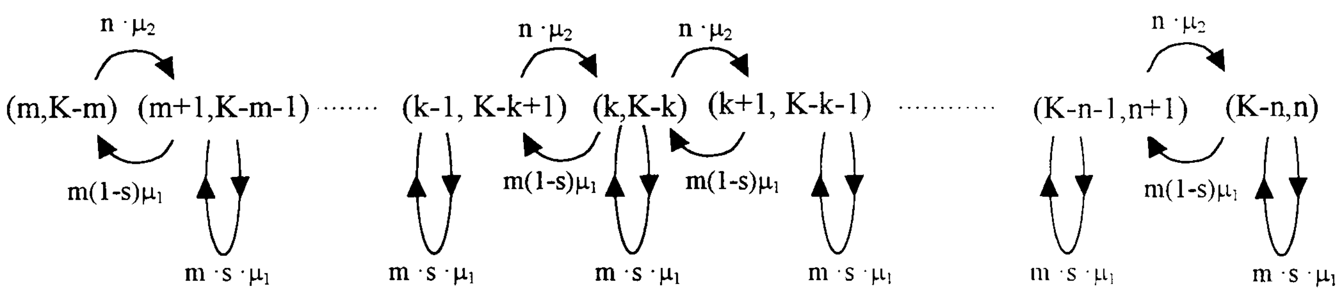
$$P(3,K-3)=\frac{n\cdot\mu_2}{3\cdot\mu_1\cdot(1-s)}\cdot\frac{n\cdot\mu_2}{2\cdot\mu_1\cdot(1-s)}\cdot\frac{n\cdot\mu_2}{1\cdot\mu_1\cdot(1-s)}\cdot p(0,K)$$

$$P(3,K-3)=\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^3\cdot\frac{n^3}{3!}\cdot p(0,K) \qquad \textbf{(C)}$$

General expression, derived from (A), (B) and (C), for P(k,K-k), $0 \le k \le m$:

$$P(k,K-k)=\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k\cdot\frac{n^k}{k!}\cdot p(0,K) \qquad \textbf{(1)}$$

2. All the repair servers 'n' are busy and all the usage servers 'm' are busy; ***m +1 ≤ k ≤ K - n***



$$P(k,K-k)=\frac{n\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot p(k-1,K-k+1)$$

P(m+1,K-m-1);

$$P(m+1,K-m-1)=\frac{n\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot p(m,K-m) \qquad \textbf{(A)}$$

P(m+2,K-m-2);

$$P(m+2,K-m-2)=\frac{n\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot p(m+1,K-m+1)$$

with equation (A)

$$P(m+2,K-m-2)=\frac{n\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot\frac{n\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot p(m,K-m)$$

$$P(m+2,K-m-2)=\left(\frac{n}{m}\right)^{2}\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^{2}\cdot p(m,K-m) \qquad \textbf{(B)}$$

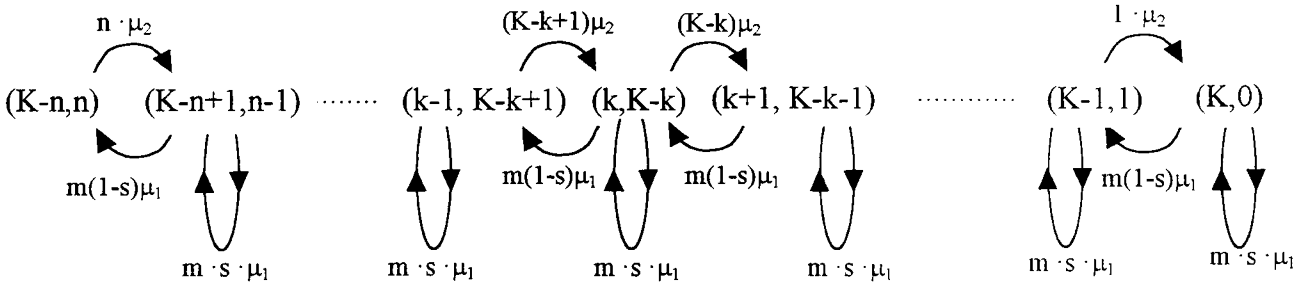
General expression;

$$P(k,K-k)=\left(\frac{n}{m}\right)^{k-m}\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^{k-m}\cdot p(m,K-m)$$

with **(1),** P(m,K-m) expressed in P(0,K) from the part 1:

$$P(k,K-k)=\left(\frac{n}{m}\right)^{k}\cdot\frac{m^m}{m!}\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^{k}\cdot p(0,K) \qquad \textbf{(2)}$$

3. All the usage servers are busy, but there is free capacity in the repair facilities; ***K-n+1≤ k ≤K***



$$P(k,K-k)=\frac{(K-k+1)\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot p(k-1,K-k+1)$$

P(K-n+1,n-1);

$$P(K-n+1,n-1)=\frac{n\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot p(K-n,n) \qquad \textbf{(A)}$$

P(K-n+2,n-2);

$$P(K-n+2,n-2)=\frac{(n-1)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot p(K-n+1,n-1)$$

with equation (A):

$$P(K-n+2,n-2)=\frac{(n-1)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot\frac{n\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot p(K-n,n) \qquad \textbf{(B)}$$

P(K-n+3,n-3);

$$P(K-n+3,n-3)=\frac{(n-2)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot p(K-n+2,n-2)$$

with equation (B):

$$P(K-n+3,n-3)=\frac{(n-2)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot\frac{(n-1)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot\frac{n\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot p(K-n,n)$$

$$P(K-n+3,n-3)=\frac{(n-2)(n-1)n\cdot\mu_2^3}{(m\cdot\mu_1(1-s))^3}\cdot p(K-n,n) \qquad \textbf{(C)}$$

$$P(k,K-k)=\frac{n(n-1)(n-2)\ldots(K-k+2)(K-k+1)}{m^{k+n-K}}\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^{k+n-K}\cdot p(K-n,n)$$

with P(K-n,n), expressed in P(0,K) from the part 2 and (A), (B) and (C),:

$$P(k,K-k)=\frac{n^{K-k}}{(K-k)!}\cdot\frac{n!}{n^n}\cdot\left(\frac{n}{m}\right)^k\cdot\frac{m^m}{m!}\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k\cdot p(0,K) \qquad \textbf{(3)}$$

Summarised:

1. For $0 \leq k \leq m$

$$P(k,K-k)=\frac{n^k}{k!}\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k p(0,K)$$

2. For $m+1 \leq k \leq K-n$

$$P(k,K-k)=\frac{m^m}{m!}\left(\frac{n}{m}\right)^k\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k p(0,K)$$

3. For $K-n+1 \leq k \leq K-n$

$$P(k,K-k)=\frac{n^{K-k}}{(K-k)!}\cdot\frac{n!}{n^n}\cdot\frac{m^m}{m!}\cdot\left(\frac{n}{m}\right)^k\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k\cdot p(0,K)$$

step 4: Calculation values of all probabilities
First the calculation of P(0,K). The total of all the probabilities must be equal to 1, from where P(0,K) can be calculated. If P(0,K) is known, all the probabilities can be calculated.

$$\sum_{k=0}^{m}\frac{n^k}{k!}\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k+\sum_{k=m+1}^{K-n}\frac{m^m}{m!}\left(\frac{n}{m}\right)^k\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k+$$

$$+\sum_{k=K-n+1}^{K}\frac{n^{K-k}}{(K-k)!}\cdot\frac{n!}{n^n}\cdot\frac{m^m}{m!}\cdot\left(\frac{n}{m}\right)^k\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k=\frac{1}{P(0,K)}$$

step 5: Performance criteria
When all the individual probabilities are calculated, the sum of the probabilities that all usage servers are bussy is defined as service rate. In formula:

$$service\ \ rate=\sum_{k=m}^{K}P(k,K-k).$$

For example; 5 items must be in use (m=5), the total number of turnaround items is 8 (K=8), the service rate is $\sum_{k=5}^{8}P(k,K-k)$, written out: P(5,3) + P(6,2) + P(7,1) + P(8,0).

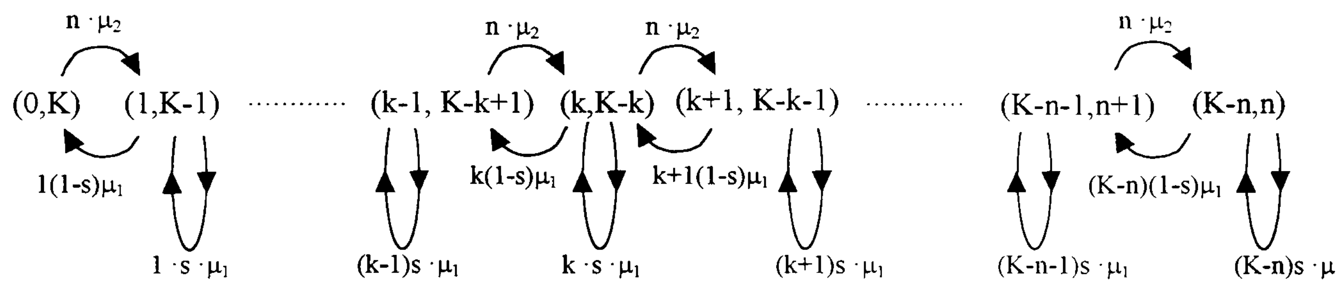
The number of items needed in the repair loop (K) is determined by iteration.

Model 2, m < K ≤ m + n

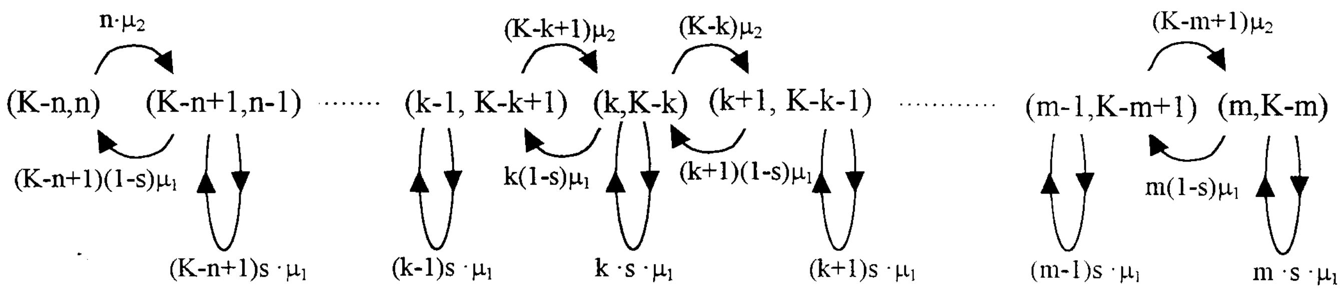
step 1: Three situations
Three situations can be distinguished in the system.

1. All the repair servers 'n' are busy, there are more items needed in use: 0 < k ≤ K - n
2. All the repair servers 'n' are **not** busy and even **not** all the usage servers 'm' are busy: K - n < k ≤ m
3. All the usage servers are busy, but there is capacity free in the repair facilities: m < k ≤ K

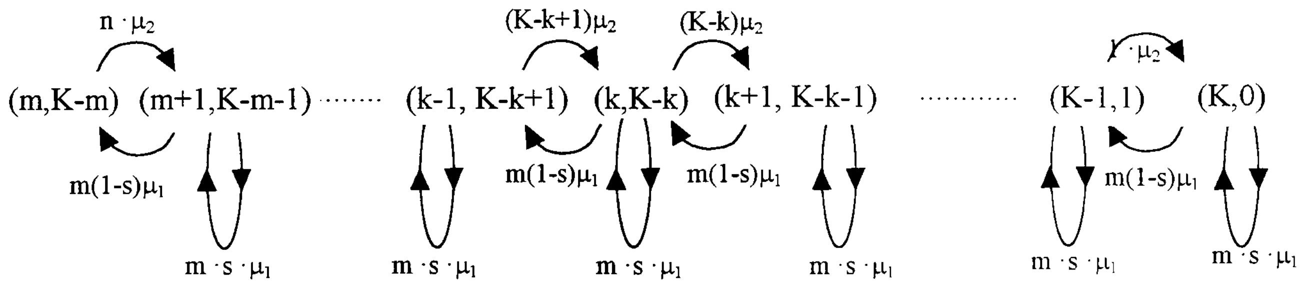
1.All the repair servers 'n' are busy, there are more items needed in use; 0 < k ≤ K - n



2.All the repair servers 'n' are ***not*** *busy and even* ***not*** *all the usage servers 'm' are busy;*
$K-n<k\leq m$



3. All the usage servers are busy, but there is free capacity in the repair facilities; $m<k\leq K$



<u>step 2: Calculation of the probabilities</u>

1. For $0\leq k\leq K\text{-}n$

$$P(k,K-k)=\frac{n\cdot\mu_2}{k\cdot\mu_1\cdot(1-s)}\cdot p(k-1,K-k+1)$$

2. For $K\text{-}n+1\leq k\leq m$

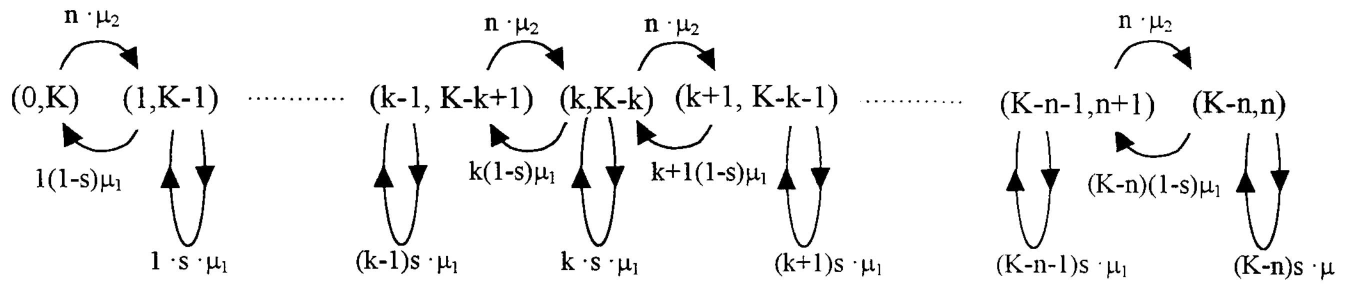
$$P(k,K-k)=\frac{(K-k+1)\cdot\mu_2}{k\cdot\mu_1\cdot(1-s)}\cdot p(k-1,K-k+1)$$

3. For $m+1\leq k\leq K$

$$P(k,K-k)=\frac{(K-k+1)\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot p(k-1,K-k+1)$$

step 3: Probabilities expressed in P(0,K);

1. All the repair servers 'n' are busy, there are more items needed in use; $0 < k \leq K - n$



General;

$$P(k,K-k) = \frac{n \cdot \mu_2}{k \cdot \mu_1 \cdot (1-s)} \cdot P(k-1,K-k+1)$$

P(1,K-1);

$$P(1,K-1) = \frac{n \cdot \mu_2}{1 \cdot \mu_1 \cdot (1-s)} \cdot P(0,K) \qquad \textbf{(A)}$$

P(2,K-2);

$$P(2,K-2) = \frac{n \cdot \mu_2}{2 \cdot \mu_1 \cdot (1-s)} \cdot P(1,K-1)$$

With equation (A):

$$P(2,K-2) = \frac{n \cdot \mu_2}{2 \cdot \mu_1 \cdot (1-s)} \cdot \frac{n \cdot \mu_2}{1 \cdot \mu_1 \cdot (1-s)} \cdot P(0,K)$$

$$P(2,K-2) = \left(\frac{\mu_2}{\mu_1 \cdot (1-s)}\right)^2 \cdot \frac{n^2}{2!} \cdot P(0,K) \qquad \textbf{(B)}$$

P(3,K-3);

$$P(3,K-3) = \frac{n \cdot \mu_2}{3 \cdot \mu_1 \cdot (1-s)} \cdot P(2,K-2)$$

With equation (B):

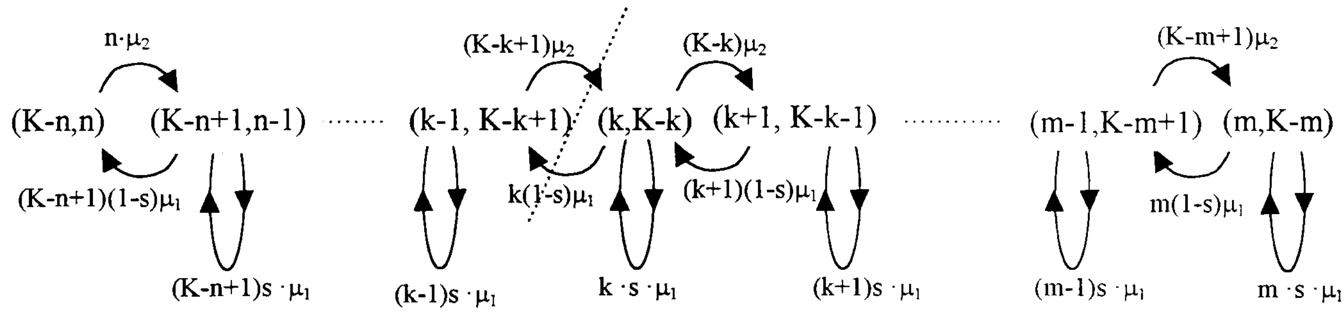
$$P(3,K-3)=\frac{n\cdot\mu_2}{3\cdot\mu_1\cdot(1-s)}\cdot\frac{n\cdot\mu_2}{2\cdot\mu_1\cdot(1-s)}\cdot\frac{n\cdot\mu_2}{1\cdot\mu_1\cdot(1-s)}\cdot P(0,K)$$

$$P(3,K-3)=\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^3\cdot\frac{n^3}{3!}\cdot P(0,K) \qquad \textbf{(C)}$$

General expression, derived from (A), (B) and (C), for P(k,K-k), $0 \le k \le K-n$:

$$P(k,K-k)=\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k\cdot\frac{n^k}{k!}\cdot P(0,K) \qquad \textbf{(1)}$$

2.All the repair servers 'n' are ***not*** *busy and even* ***not*** *all the usage servers 'm' are busy;*
K - n < k ≤ m



General;

$$P(k,K-k)=\frac{(K-k+1)\cdot\mu_2}{k\cdot\mu_1\cdot(1-s)}\cdot P(k-1,K-k+1)$$

P(K-n+1,n-1);

$$P(K-n+1,n-1)=\frac{n\cdot\mu_2}{(K-n+2)\cdot\mu_1\cdot(1-s)}\cdot P(K-n,n) \qquad \textbf{(A)}$$

P(K-n+2,n-2);

$$P(K-n+2,n-2)=\frac{(n-1)\cdot\mu_2}{(K-n+2)\cdot\mu_1\cdot(1-s)}\cdot P(K-n+1,n-1)$$

With equation (A):

$$P(K-n+2,n-2)=\frac{(n-1)\cdot\mu_2}{(K-n+2)(1-s)\cdot\mu_1}\cdot\frac{n\cdot\mu_2}{(K-n+1)\cdot\mu_1\cdot(1-s)}\cdot P(K-n,n) \qquad \textbf{(B)}$$

P(K-n+3,n-3);

$$P(K-n+3,n-3)=\frac{(n-2)\cdot\mu_2}{(K-n+3)\cdot\mu_1\cdot(1-s)}\cdot P(K-n+2,n-2)$$

with equation (B):

$$P(K-n+3,n-3)=\frac{(n-2)\cdot(n-1)\cdot n}{(K-n+3)(K-n+2)(K-n+1)}\cdot\left(\frac{\mu_2}{\cdot\mu_1\cdot(1-s)}\right)^3\cdot P(K-n,n) \qquad \textbf{(C)}$$

P(K-n,n) expressed in P(0,K), calculated from (1);

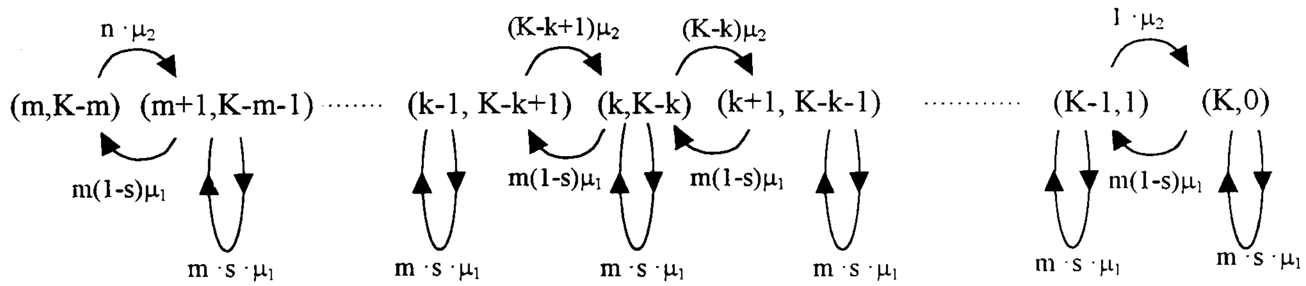
$$P(K-n,n)=\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^{K-n}\cdot\frac{n^{(K-n)}}{(K-n)!}\cdot P(0,K) \qquad \textbf{(D)}$$

General expression derived from (A), (B), (C) and (D):

$$P(k,K-k)=\frac{n(n-1)(n-2).......(K-k+2)(K-k+1)}{(K-n+1)(K-n+2)(K-n+3)......(k-1)k}\cdot\left(\frac{\mu_2}{\cdot\mu_1\cdot(1-s)}\right)^k\frac{n^{K-n}}{(K-n)!}\cdot P(0,K)$$

$$P(k,K-k)=\frac{n!}{(K-k)!}\cdot\frac{k!+n^{K-n}}{(K-n)!}\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k\cdot P(0,K) \qquad \textbf{(2)}$$

3. All the usage servers are busy, but there is free capacity in the repair facilities; $\mathbf{m < k \leq K}$



General;

$$P(k,K-k)=\frac{(K-k+1)\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot P(k-1,K-k+1)$$

P(m+1,K-m-1);

$$P(m+1,K-m-1)=\frac{(K-m)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot P(m,K-m) \qquad \textbf{(A)}$$

P(m+2,K-m-1);

$$P(m+2,K-m-2)=\frac{(K-m-1)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot P(m+1,K-m-1)$$

with equation (A):

$$P(m+2,K-m-2)=\frac{(K-m-1)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot\frac{(K-m)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot P(m,K-m) \qquad \textbf{(B)}$$

P(m+3,K-m-3);

$$P(m+3,K-m-3)=\frac{(K-m-2)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot P(m+2,K-m-2)$$

with equation (B):

$$P(m+3,K-m-3)=\frac{(K-m-2)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot\frac{(K-m-1)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot\frac{(K-m)\cdot\mu_2}{m\cdot\mu_1\cdot(1-s)}\cdot P(m,K-m)$$

$$P(m+3,K-m-3)=\frac{(K-m-2)(K-m-1)(K-m)\cdot\mu_2^3}{(m\cdot\mu_1(1-s))^3}\cdot P(m,K-m) \qquad \textbf{(C)}$$

General expression for P(0,K) if $m < k \leq K$;

$$P(k,K-k)=\frac{(K-m)!}{m\cdot(K-k)!}\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^{k-m}\cdot P(m,K-m)$$

P(m,K-m) expressed in P(0,K), calculated from (2);

$$P(m,K-m)=\frac{n!}{(K-m)!}\cdot\frac{m!+n^{K-n}}{(K-n)!}\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^m\cdot P(0,K) \qquad \textbf{(D)}$$

General expression derived from (A), (B), (C) and (D):

$$P(k,K-k)=\frac{n!}{(K-k)!}\cdot\frac{(m-1)!+n^{K-n}}{(K-n)!}\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k\cdot P(0,K) \qquad \textbf{(3)}$$

Summarised:

1. For $0 \le k \le K - n$

$$P(k,K-k)=\frac{n^k}{k!}\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k p(0,K)$$

2. For $K - n + 1 \le k \le m$

$$P(k,K-k)=\frac{n!}{(K-k)!}\cdot\frac{k!}{(K-n)!}\cdot\frac{n^{K-n}}{(K-n)!}\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k p(0,K)$$

3. For $m + 1 \le k \le K$

$$P(k,K-k)=\frac{n^{K-k}}{(K-k)!}\cdot\frac{n!}{n^n}\cdot\frac{m^m}{m!}\cdot\left(\frac{n}{m}\right)^k\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k\cdot p(0,K)$$

step 4: Calculation values of all probabilities

$$\sum_{k=0}^{K-n}\frac{n^k}{k!}\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k+\sum_{k=K-n+1}^{m}\frac{n!}{(K-k)!}\cdot\frac{k!}{(K-n)!}\cdot\frac{n^{K-n}}{(K-n)!}\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k+$$

$$+\sum_{k=m+1}^{K}\frac{n^{K-k}}{(K-k)!}\cdot\frac{n!}{n^n}\cdot\frac{m^m}{m!}\cdot\left(\frac{n}{m}\right)^k\cdot\left(\frac{\mu_2}{\mu_1\cdot(1-s)}\right)^k=\frac{1}{P(0,K)}$$

step 5: Performance criteria
See model 1.

Descriptions of the selected items.

Group (1)

1. NSN : 2520 008949533

GRCL: 2520
Vehicular power transmission components
Includes transfer transmission assemblies; clutch assemblies; universal joints; propeller shafts; automotive torque converters; power takeoffs.

NIIN: 008949533
No Data available, Transmission and Co

MG: 55
Field artillery, Components and spare parts

2. NSN : 2530 121675887

GRCL: 2530
Vehicular brake, steering, axle, wheel, and track components
Includes turret brakes; clutch brakes, tank turret.

NIIN : 121675887
INC: 21992
Track shoe, vehicular
A replacement shoe for a tracked vehicle, which may include attaching parts, such as pin(s), guide(s), link(s), and the like. Excludes links with integral or attached shoes.

MG : 52
Air-target artillery, spare parts Leopard 1, under frames and derived versions

3. NSN : 2930 121430186

GRCL: 2930
Engine cooling system components, non-aircraft
Includes cooling fans; radiators; water pumps; water hose assemblies; engine coolant filters; components for all engines except aircraft and guided missile prime moving.

NIIN : 121430186
INC: 22138
Radiator, engine coolant
Aircraft and guided missile prime mover types, except aircraft and guided missile prime moving a heat transfer device having a tank(s) and core(s) specifically designed to reduce the temperature of the liquid in an internal combustion engine cooling system. Excludes engine oil cooler radiators.

MG : 52
Air-target artillery, spare parts Leopard 1, under frames and derived versions

4. NSN : 2540 121456305

GRCL: 2540
Vehicular furniture and accessories
Includes automobile seat covers; shock absorber; bumper, windshield wipers; bumper guards; mirrors, rear view and side view; vehicle heaters; vehicular furniture.
Excludes speedometers; suspension type shock absorbers.

NIIN : 121456305
INC: 30410
Pump, Rotary
A positive displacement device which utilises the rotating motion of one or more gears, cams, vanes or screws in an enclosure as a means of transferring a liquid from one place to another. It is designed to be driven manually or by a prime mover which is not an integral part of the pump.
Excludes aircraft engine pump

MG : 52
Air-target artillery, spare parts Leopard 1, under frames and derived versions

5. NSN: 2530 001359035

GRCL: 2530
Vehicular brake, steering, axle, wheel, and track components
Includes turret brakes; clutch brakes, tank turret.

NIIN : 001359035
INC: 61447
Lever, manual control
A rigid item of various shapes and cross-sections, specifically designed to manually actuate and/or regulate a variety of mechanisms. It usually has an integral hand grip, knob, or the like, or provisions for the mounting of the same. It may have accommodations for locking and/or positioning. The point of fulcrum may be an integral shaft perpendicular to the axis or a through hole to provide a definite means of securing, and usually has additional accommodation (s) for attachment of connecting link, rigid; wire rope assembly, single leg; and clevis, rod end; etc..
Excludes arm (as modified); lever, remote control; and bell crank except nuclear ordnance miscellaneous hardware miscellaneous power transmission equipment.

MG : 55
Field artillery, Components and spare parts

group (2)

1. NSN: 4210 121405395

GRCL: 4210
Fire fighting equipment
Includes fire extinguishers; fire axes; fire rakes; fire beaters; fire trucks; fire hose; play pipes; hose fittings having one or more fire hose end connections; fire hose reels; fire fighting trailers; fire hydrants; sprinkler heads.
Excludes wrecking bars.

NIIN : 121405395
No definition defined (CD-NMCRL)

MG : 52
Air-target artillery, spare parts Leopard 1, under frames and derived versions

2. NSN: 4320 006799643

GRCL: 4320
Power and hand pumps
Excludes laboratory jet pumps.

NIIN : 006799634
INC: 30410
Pump, Rotary
A positive displacement device which utilises the rotating motion of one or more gears, cams, vanes or screws in an enclosure as a means of transferring a liquid from one place to another. It is designed to be driven manually or by a prime mover which is not an integral part of the pump.
Excludes aircraft engine pump

MG : 45
Components and Spare parts of the YPR 765 family

3. NSN: 6150 009999842

GRCL: 6150
Miscellaneous electric power and distribution equipment
Includes appliance and extension cords; electric power and distribution cable with attachments, multiplication; common components of electrical rotating equipment, such as end bells and frames.

NIIN : 009999842
INC: 00450
Wiring Harness
An item consisting of two or more individually insulated conductors (solid, standed, or tinsel) of a definite length, with or without shielding, held together by lacing cord, metal bands, or similar

type binding. The individual conductors are usually identified by colour, or by alphabetically numeric codes or symbols. The item may include fittings which provide for connection to other items. Excludes items which are branched, forked, jacketed, sleeved or contained in a common covering. Also exclude cable assembly (as modified); harness, electrical equipment; lead assembly, electrical; and wiring harness, branched communications except communications

MG : 55
Field artillery, Components and spare parts

4. NSN: 5120 121771825

GRCL: 5120
Hand tools, non-edged, non-powered
Includes hammers; picks; pliers, except pliers for cutting only; screwdrivers; shovels; construction rakes, forks and hoes; jacks, including contractors' jacks; wrecking bars; glue pots; blowtorches. Excludes craftsman's measuring tools; gardening rakes, forks, hoes, and other garden tools.

NIIN : 121771825
INC: 30273
Wrench (1), ratchet
A single or double end wrench having a reversible or non reversible ratchet socket on one or both end. One end may have a fixed socket or hand grip. It may have a wrench opening through the handle. For items with drive tand, see handle, wicket wrench.

MG : 42
Leopard 2, spare parts, equipment parts and special equipment

group (3)

1. NSN: 2815 121428750

GRCL: 2815
Diesel engines and components
Includes automotive, industrial, marine, locomotive, and all other types of diesel and semi-diesel engines.
Excludes engines accessories.

NIIN : 121428750
No definition defined (CD-NMCRL)

MG : 42
Leopard 2, spare parts, equipment parts and special equipment

2. NSN: 2530 005370372

GRCL: 2530
Vehicular brake, steering, axle, wheel, and track components
Includes turret brakes; clutch brakes, tank turret.

NIIN : 005370372
INC: 61478
Arm assembly, pivot, track suspension
An item of rigid construction, which is a component of the track suspension of track laying vehicles. It is specifically designed to pivot at one end and to accommodate a road wheel or a compensating idler wheel on the other, and has provisions for mountain a torsion bar, suspension at the pivoting axis. It may include spindle(s), bearing(s), hub(s), and the like, and may have provisions for mounting a shock absorber and/or a track adjusting link.

MG : 55
Field artillery, Components and spare parts

3. NSN: 2520 000156669

GRCL: 2520
Vehicular power transmission components
Includes transfer transmission assemblies; clutch assemblies; universal joints; propeller shafts; automotive torque converters; power takeoffs.

NIIN : 000156669
No definition defined (CD-NMCRL)

MG : 46
Components and spare parts M113 family

group (4)

1. NSN: 4210 121429961

GRCL: 4210
Fire fighting equipment
Includes fire extinguishers; fire axes; fire rakes; fire beaters; fire trucks; fire hose; play pipes; hose fittings having one or more fire hose end connections; fire hose reels; fire fighting trailers; fire hydrants; sprinkler heads.
Excludes wrecking bars.

NIIN : 121429961
No definition defined (CD-NMCRL)

MG : 42
Leopard 2, spare parts, equipment parts and special equipment

2. NSN: 2520 121469610

GRCL: 2520
Vehicular power transmission components
Includes transfer transmission assemblies; clutch assemblies; universal joints; propeller shafts; automotive torque converters; power takeoffs.

NIIN : 121469610
No definition defined (CD-NMCRL)

MG : 52
Air-target artillery, spare parts Leopard 1, under frames and derived versions

3. NSN: 2530 121455794

GRCL: 2530
Vehicular brake, steering, axle, wheel, and track components
Includes turret brakes; clutch brakes, tank turret.

NSN: 121455794
INC: 60405
Disc, brake
A flat circular metallic item, a component of a disk type brake used primarily for frictional purpose aircraft hydraulic systems aircraft landing gear miscellaneous power transmission vehicular.

MG : 52
Air-target artillery, spare parts Leopard 1, under frames and derived versions

group (5)

1. NSN: 1240 121463685

GRCL: 1240
Optical sighting and ranging equipment
Includes periscopes for submarines; range and height finders; telescopic sights; optical instruments integrated with fire control equipment.

NIIN : 121463685
No definition defined (CD-NMCRL)

MG : 43
Leopard-1, fight tanker, tower

2. NSN: 1015 999604296

GRCL: 1015
Guns, 75 mm through 125 mm
Includes breech mechanisms; mounts; rammers.

NIIN : 999604296
No definition defined (CD-NMCRL)

MG : 46
Components and spare parts M113 family

3. NSN: 2590 009992122

GRCL: 2590
Miscellaneous vehicular components
Includes attachments for tanks, self-propelled weapons, and high speed tractors; a-frames and winches specifically designed for truck mounting; cranes and crane booms for wrecker trucks.

NIIN : 009992122
INC: 61971
Tank section, fluid
One or more like or unlike sections of a fluid tank which when assembled compose a complete tank. Either or all sections may have provisions for the attachment of fitting, filler cap, mounting brackets, or the like. It is used primarily in connection with fuel, hydraulic, oil, or water system.

MG : 46
Components and spare parts M113 family

group (6)

1. NSN: 6650 121719741

GRCL: 6650
Optical instruments, test equipment, components and accessories
Note: Optical instruments which are designed for integral use with other assemblies or equipment such as periscopes for submarines and optical devices for use in fire control equipment, are excluded from this lass and should be classified in the same class as their next higher assemblies. High vision equipment is classified in group 58. This class includes items designed for optical testing. Includes binoculars; magnifiers; microscopes; periscopes; telescopes; optical elements; such as lens, prisms, windows; optical benches and associated devices; endoscopes, fibber optics (non-medical).
Excludes fire control instruments, optical; surveying instruments, optical; photo-grammetric instruments; octants; and sextants; optical instruments integrated with fire control equipment; opthalmological instruments; electronic fibre optic test equipment; medical endoscopes.

NIIN : 121719741
INC: 45605
Periscope (1), armoured vehicle
A rectangular or cylindrical periscope, usually positioned in a holder, or mount within an vehicle. It is used to observe terrain, near and distant targets, and the like. It may also be linked to gun-training mechanisms for integration of movement for fire control purposes except fire control.

MG : 52
Air-target artillery, spare parts Leopard 1, under frames and derived versions

2. NSN: 2540 121873068

GRCL: 2540
Vehicular furniture and accessories
Includes automobile seat covers; shock absorber; bumper, windshield wipers; bumper guards; mirrors, rear view and side view; vehicle heaters; vehicular furniture.
Excludes speedometers; suspension type shock absorbers.

NIIN : 121873068
INC: 36252
Mirror Head, Vehicular
An item or metal or metal-coated glass encased in a frame which is designed for attachment to various types of mounting brackets. May be round, square or rectangular in shape and may be convex. A heating device may be included. The items does not include mounting brackets/hardware. Excluded mirror assembly, rear-view and mirror, rear-view.

MG : 52
Air-target artillery, spare parts Leopard 1, under frames and derived versions

3. NSN : 2590 121455960

GRCL: 2590
Miscellaneous vehicular components
Includes attachments for tanks, self-propelled weapons, and high speed tractors; a-frames and winches specifically designed for truck mounting; cranes and crane booms for wrecker trucks.

NIIN : 121455960
No definition defined (CD-NMCRL)

MG : 52
Air-target artillery, spare parts Leopard 1, under frames and derived versions

group (7)

1. **NSN: 2520 121431077**

GRCL: 2520
Vehicular power transmission components
Includes transfer transmission assemblies; clutch assemblies; universal joints; propeller shafts; automotive torque converters; power takeoffs.

NIIN : 121431077
INC: 21951
Flange, companion, universal joint
An item having a flange on one end with provisions for a shaft on the other end. Designed to mate with the flange of a yoke, universal joint, for the purpose of transmitting rotary motion multi application vehicular power transmission components.

MG : 52
Air-target artillery, spare parts Leopard 1, under frames and derived versions

2. **NSN: 2920 007279884**

GRCL: 2920
Engine electrical system components, non-aircraft
Includes generators; magnetos; spark plugs; ignition coils; ignition distributors; engine voltage regulators; ignition harness assemblies; starting motors for engines.
Excludes vehicular lighting fixtures and aircraft generators.

NIIN : 007279884
INC: 00462
Rotor (1), Generator
A rotor which is a part of an alternating current generator. See also armature, generator engine, aircraft engine, except aircraft except engine and tachometer.

MG : 55
Field artillery, Components and spare parts

3. **NSN: 2910 121428179**

GRCL: 2920
Engine fuel system components, non-aircraft
Includes carburettors; fuel pumps; engine fuel engines; fuel tanks; components for all engines except aircraft and guided missile prime moving.

NIIN : 121428179
INC: 32622
Filter (1), fluid

A filter having inlet and outlet connections and design to be connected in a pipe, tube or hose line. For spin-on, base-mounted filtering devices with integral outer casings, see filter element, fluid. Excludes air conditioner aircraft breathing oxygen aircraft hydraulic, vacuum, and de-icing system centrifugal, separators and vacuum filter cleaners, aircraft cleaners, non-aircraft engine fuel system components, aircraft engine fuel system components, non-aircraft medical opthalmological suction filters.

MG : 52
Air-target artillery, spare parts Leopard 1, under frames and derived version

Abbreviations:

NSN	NATO Stock Number
NIIN	NATO Item Identification Number
INC	Item Name Code
GRCL	Group and Class
MG	Material Group

Sources:

GRCL:	Acodp-2 (edition 2), NATO supply classification handbook, group and classes, February 1995, an Allied Codification Publication
INC:	NATO Master Cross Reference List (CD-NMCRL), version 2.0g
MG:	Department of Defence, Netherlands; Documentation of 'Cenraal Voorraad Beheersingssysteem van de Koninklijke Landmacht (CVBKL)'; dd. 01-10-96

GROUP	NIIN		SOR	NIU	NISS	NIUS	NIR	R94-4	R95-1	R95-2	R95-3	R95-4	R96-1	R96-2	R96-3
(1) YYY	008949533	BE			14	6	0				0	0	0	0	0
(all)		GY	C	?	89	5	34	18	9	11	15	10	19	12	15
		NE	S	135	25	2	11	7	4	4	3	3	3	3	3
	121675887	BE			1716	4991	2226				4258	2530	194	1384	344
		GY	C	?	6529	5745	4852	8605	5270	9370	10037	6633	14350	7475	3710
		NE	S	52	42	0	0	0	0	0	0	0	0	0	0
	121430186	BE			1	5	5				0	0	0	0	0
		GY	C	?	393	138	10	42	42	49	28	46	38	24	27
		NE	C	320	134	18	0	1	2	3	2	1	7	5	4
	121456305	BE			16	31	17				0	4	0	4	1
		GY	C	?	114	30	18	21	48	26	25	35	30	25	19
		NE	S	160	108	9	0	2	5	3	2	4	7	6	1
	001359035	BE			0	0	0				0	0	0	0	0
		GY	C	?	238	12	0	2	0	1	1	0	3	0	5
		NE	S	252	3	0	0	0	2	1	1	0	0	3	1
(2) YYN	121405395	BE			7	3	0				0	0	0	0	0
BE/GY		GY	C	?	399	40	0	11	6	20	11	2	62	4	5
		NE	X	X	X	X	X	3	0	1	0	0	0	0	0
	006799643	BE			59	2	2				0	6	2	0	0
		GY	C	?	26	98	0	144	27	65	44	33	45	28	50
		NE	X	X	X	X	X	11	10	10	4	7	5	10	11
	009999842	BE			25	2	0				0	2	0	0	3
		GY	CONSUMABLE!!! MISTAKE FIRST DB!!					4	4	0	0	7	1	2	2
		NE	X	X	X	X	X	3	4	0	0	4	1	0	1
	121771825	BE			0	2	8				8	4	6	0	8
		GY	C	?	1093	99	6	78	81	57	46	48	88	69	31
		NE	X	X	X	X	X	8	19	14	18	16	9	6	10
(3) YNY	121428750	BE			50	1	5				4	0	2	0	3
BE/NE		GY	X	X	601	X	X	0	0	0	0	0	0	0	0
		NE	C	776	41	0	0	0	0	0	0	0	0	0	0
	005370372	BE			39	52	7				0	0	0	0	0
		GY	X	X	78	X	X	0	22	1	11	0	2	8	0
		NE	S	1260	95	40	0	1	0	1	0	0	0	0	0
	000156669	BE			18	0	8				0	2	2	4	2
		GY	X	X	65	X	X	6	0	0	0	1	1	2	0
		NE	C	2000	5	0	0	0	0	15	35	19	7	5	11
(4) YNN	121429961	BE			76	43	75				15	18	17	100	1
BE		GY	X	X	1352	X	X	289	184	136	235	183	174	252	97
		NE	X	X	X	X	X	7	8	4	8	19	13	53	20
	121469610	BE			69	0	26				12	20	6	12	6
		GY	X	X	595	X	X	0	6	0	0	0	0	0	0
		NE	X	X	X	X	X	3	0	5	0	0	1	0	1

GROUP	NIIN		SOR	NIU	NISS	NIUS	NIR	R94-4	R95-1	R95-2	R95-3	R95-4	R96-1	R96-2	R96-3
	121455794	BE			454	21	112				28	32	22	60	32
		GY	X	X	0	X	X	67	86	71	50	106	240	69	87
		NE	X	X	X	X	X	1	4	6	0	0	0	0	0
(5) NYY	121463685	BE			16	0	0				0	0	0	0	0
GY/NE		GY	C	?	353	0	0	0	0	0	0	0	0	0	0
		NE	C	286	10	0	0	0	0	0	0	0	0	0	0
	999604296	BE			28	0	0				0	0	0	0	0
		GY	C	?	826	0	0	0	0	0	0	0	6	1	0
		NE	S	286	35	2	0	0	0	0	0	0	0	0	0
	009992122	BE			38	0	0				1	0	6	0	0
		GY	C	?	4	1	0	2	6	7	0	3	4	0	4
		NE	S	312	4	2	0	0	0	1	1	1	0	0	0
(6) NYN	121719741	BE	X	X	829	0	102				119	42	76	72	32
GY		GY	C	?	16138	2667	0	1531	860	1413	643	1282	1150	318	524
		NE	X	X	X	X	X	64	94	36	18	18	190	41	53
	121873068	BE	X	X	328	4	33				0	0	0	0	0
		GY	C	?	4655	8	0	169	120	95	91	44	174	58	40
		NE	X	X	X	X	X	9	18	17	8	12	21	29	23
	121455960	BE	X	X	1	0	0				0	0	0	0	0
		GY	C	?	71	0	0	2	3	3	5	3	3	3	1
		NE	X	X	X	X	X	0	1	2	1	1	0	0	1
(7) NNY	121431077	BE	X	X	132	0	33				0	0	0	16	35
NE		GY	X	X	1332	X	X	0	5	0	10	0	9	7	0
		NE	?	150	25	0	0	1	0	0	0	0	0	0	0
	007279884	BE	X	X	40	0	14				14	0	6	2	2
		GY	X	X	0	X	X	0	0	0	0	0	0	6	16
		NE	?	126	79	0	0	0	0	0	1	0	0	0	0
	121428179	BE	X	X	23	0	10				0	0	1	0	0
		GY	X	X	231	X	X	13	16	12	0	4	8	3	22
		NE	?	150	313	0	0	3	0	1	0	1	0	0	1

GROUP	NIIN		P94-4	P95-1	P95-2	P95-3	P95-4	P96-1	P96-2	P96-3	S94-4	S95-1	S95-2	S95-3	S95-4	S96-	S96-2	S96-3
(1) YYY	008949533	BE												0	0	0	0	0
(all)		GY	0	0	0	0	0	0	0	0	1%	1%	1%	1%	1%	1%	1%	1%
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	121675887	BE						1152	1245					880	962	1028	349	253
		GY	OVER 94-96 1000 STUKS PROCURED								80%	80%	80%	80%	80%	80%	80%	80%
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	121430186	BE												0	0	0	0	0
		GY	OVER 94-96 10 STUKS PROCURED								1%	1%	1%	1%	1%	1%	1%	1%
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	121456305	BE												0	2	1	1	1
		GY	OVER 94-96 20 STUKS PROCURED								34%	34%	34%	34%	34%	34%	34%	34%
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	001359035	BE												0	0	0	0	0
		GY	OVER 94-96 0 STUKS PROCURED								0%	0%	0%	0%	0%	0%	0%	0%
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(2) YYN	121405395	BE												0	0	0	0	0
BE/GY		GY	OVER 94-96 6 STUKS PROCURED								21%	21%	21%	21%	21%	21%	21%	21%
		NE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	006799643	BE												0	3	2	0	0
		GY	OVER 94-96 0 STUKS PROCURED								1%	1%	1%	1%	1%	1%	1%	1%
		NE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	009999842	BE												0	1	0	0	3
		GY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		NE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	121771825	BE												6	2	3	0	3
		GY	OVER 94-96 25 STUKS PROCURED								38%	38%	38%	38%	38%	38%	38%	38%
		NE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
(3) YNY	121428750	BE												2	0	1	0	3
BE/NE		GY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	005370372	BE												0	0	0	0	0
		GY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		NE	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0
	000156669	BE												0	1	2	1	1
		GY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		NE	0	50	0	0	0	25	0	25	0	0	0	0	0	0	0	0
(4) YNN	121429961	BE						30						24	9	17	50	1
BE		GY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		NE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	121469610	BE												7	8	3	5	4
		GY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		NE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

GROUP	NIIN		P94-4	P95-1	P95-2	P95-3	P95-4	P96-1	P96-2	P96-3	S94-4	S95-1	S95-2	S95-3	S95-4	S96-	S96-2	S96-3
	121455794	BE												14	13	25	12	16
		GY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		NE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
(5) NYY	121463685	BE	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0
GY/NE		GY	OVER 94-96 0 STUKS PROCURED								1%	1%	1%	1%	1%	1%	1%	1%
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	999604296	BE	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0
		GY	OVER 94-96 0 STUKS PROCURED								10%	10%	10%	10%	10%	10%	10%	10%
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	009992122	BE	X	X	X	X	X	X	X	X	X	X	X	1	0	1	0	0
		GY	OVER 94-96 0 STUKS PROCURED								0%	0%	0%	0%	0%	0%	0%	0%
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(6) NYN	121719741	BE	X	X	X	250	X	X	90	X	X	X	X	19	35	84	11	5
GY		GY	OVER 94-96 0 STUKS PROCURED								1%	1%	1%	1%	1%	1%	1%	1%
		NE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	121873068	BE	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0
		GY	OVER 94-96 0 STUKS PROCURED								0%	0%	0%	0%	0%	0%	0%	0%
		NE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	121455960	BE	X	X	X	X	X	X	X	X	X	X	X	0	0	0	0	0
		GY	OVER 94-96 0 STUKS PROCURED								0%	0%	0%	0%	0%	0%	0%	0%
		NE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
(7) NNY	121431077	BE	X	X	X	X	X	X	X	X	X	X	X	0	9	0	8	25
NE		GY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	007279884	BE	X	X	X	X	X	X	X	X	X	X	X	4	1	2	1	4
		GY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	121428179	BE	X	X	X	X	X	X	X	X	X	X	X	0	0	6	0	0
		GY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		NE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

GROUP	NIIN		ART(wks)	PLT(wks)	MBS	ARC(us$)	PP(us$)	DIR/INDIR.	WHY_REP?	WHY_CONS?
(1) YYY	008949533	BE	41	61		9284.59	4730.56			X
(all)		GY	54	39		0.00	64761.85	?	D	X
		NE	12	43		706.8	81764.71	INDIR	A	X
	121675887	BE	12	17		178.38	385.22			X
		GY	22	52		199.03	379.12	?	D	X
		NE	?	104		-	400.00	INDIR	A	X
	121430186	BE	39	26		1648.51	5319.32			X
		GY	29	130		425.87	5234.88	?	D	X
		NE	?	65		-	5817.65	INDIR	A	X
	121456305	BE	12	48		209.22	587.32			X
		GY	29	117		382.96	578.00	?	D	X
		NE	?	69		-	641.18	INDIR	A	X
	001359035	BE	0	104		0.00	398.75			X
		GY	-	39		-	242.44	?	D	X
		NE	3	74		100.00	305.88	INDIR	A	X
(2) YYN	121405395	BE	43	30		0.00	3361.54			X
BE/GY		GY	36	78		92.32	3308.20	?	D	X
		NE	X	65	X	X	2811.76	X	X	D
	006799643	BE	38	26		108.11	325.11			
		GY	26	39		3.70	486.87	?	D	X
		NE	X	39	X	X	479.41	X	X	A
	009999842	BE	41	69		186.49	41.21			
		GY	X	?	X	X	16.33	X	X	E
		NE	X	30	X	X	17.65	X	X	A
	121771825	BE	41	39		202.70	148.45			
		GY	37	130		34.84	146.08	?	D	X
		NE	X	65	X	X	150.00	X	X	A
(3) YNY	121428750	BE	38	35		0.00	2817.67			
BE/NE		GY	X	130	X	X	2772.95	X	X	E
		NE	0	108		-	3082.35	INDIR	A	
	005370372	BE	41	43		396.59	1833.43			
		GY	X	39	X	X	847.54	X	X	E
		NE	3	26		550.00	1070.59	INDIR	A	X
	000156669	BE	41	43		0.00	385.93			
		GY	X	13	X	X	396.27	X	X	E
		NE	?	13		-	538.24	INDIR	A	X
(4) YNN	121429961	BE	12	22		0.00	771.09			
BE		GY	X	78	X	X	758.85	X	X	E
		NE	X	22	X	X	1152.94	X	X	D
	121469610	BE	12	30		0.00	1254.41			
		GY	X	130	X	X	1234.50	X	X	E
		NE	X	108	X	X	1370.59	X	X	D

GROUP	NIIN		ART(wks)	PLT(wks)	MBS	ARC(us$)	PP(us$)	DIR/INDIR.	WHY_REP?	WHY_CONS?
	121455794	BE	41	30		72.97	1081.70			
		GY	X	?	X	X	1064.53	X	X	E
		NE	X	104	X	X	970.59	X	X	D
(5) NYY	121463685	BE	12	30	X	X	2564.58	X	X	
GY/NE		GY	26	82			2523.87	?	D	X
		NE	1	87		70.00	2370.59	INDIR	A	X
	999604296	BE	49	13	X	X	826.77	X	X	
		GY	26	130			813.64	?	D	X
		NE	1	74		70.00	905.88	INDIR	A	X
	009992122	BE	41	43	X	X	227.78	X	X	
		GY	0	13			314.90	?	D	X
		NE	?	13		-	426.47	INDIR	A	X
(6) NYN	121719741	BE	12	22	X	X	155.74	X	X	
GY		GY	20	61		6.30	153.28	?	D	X
		NE	X	65	X	X	152.94	X	X	A
	121873068	BE	41	35	X	X	32.51	X	X	
		GY	0	130			31.99	?	D	X
		NE	X	74	X	X	35.29	X	X	A
	121455960	BE	12	26	X	X	238.06	X	X	
		GY	0	130			234.30	?	D	X
		NE	X	61	X	X	261.76	X	X	A
(7) NNY	121431077	BE	41	35	X	X	756.80	X	X	
NE		GY	X	96	X	X	744.80	X	X	E
		NE	?	108		?	829.41	INDIR	A	X
	007279884	BE	39	43	X	X	407.31	X	X	
		GY	X	39	X	X	344.52	X	X	E
		NE	?	30		?	450.00	INDIR	A	X
	121428179	BE	39	17	X	X	467.61	X	X	
		GY	X	69	X	X	460.20	X	X	E
		NE	?	104		?	511.76	INDIR	A	X

Step 1: Evaluation of global current stock level, Item by item discussion

Item > 10 year in stock (8 items);

001359035

	BE	GY	NE	total
Repairable Y/N	Y	Y	Y	
Average Replacement per year:	0	6	4	10
Scrapped items	-	0	0	0
Average repair costs (US$)	?	?	100.00	
Procurement Lead Times (wks)	104	39	74	
Yearly savings (US$)	-	600.00	400.00	1000.00

The calculated savings are based on the Dutch Average repair costs

Global Out of Stock Period: 24.1 year
Global Serviceable Stock value: $ 40 035.45
Global yearly demand value: $ 2 104.00

121428750

	BE	GY	NE	total
Repairable Y/N	Y	N	Y	
Average Replacement per year:	7	0	0	7
Scrapped items	5	-	-	5
Average repair costs (US$)	?	-	?	
Procurement Lead Times (wks)	35	130	108	
Yearly savings (US$)	?	-	?	?

Global Out of Stock Period: 96.1 year
Global Serviceable Stock value: $ 1 747 253.00
Global yearly demand value: $ 18 183.41

121469610

	BE	GY	NE	total
Repairable Y/N	Y	N	N	
Average Replacement per year:	46	0	5	51
Scrapped items	21	-	-	0
Average repair costs (US$)	?	-	-	
Procurement Lead Times (wks)	30	130	108	
Yearly savings (US$)	?	-	-	

Global Out of Stock Period: 13.1 year
Global Serviceable Stock value: $ 787 736.20
Global yearly demand value: $ 59 301.95

121463685

	BE	GY	NE	total
Repairable Y/N	N	Y	Y	
Average Replacement per year:	0	0	0	0
Scrapped items	-	-	-	0
Average repair costs (US$)	?	?	70.00	
Procurement Lead Times (wks)	30	82	87	
Yearly savings (US$)	-	-	-	-

Last two year, not one replacement in one of the AF's has occurred.

Global Out of Stock Period: ∞
Global Serviceable Stock value: $ 838 731.82
Global yearly demand value: $ 0.00

999604296

	BE	GY	NE	total
Repairable Y/N	N	Y	Y	
Average Replacement per year:	0	4	0	4
Scrapped items	-	1	-	1
Average repair costs (US$)	-	?	70.00	
Procurement Lead Times (wks)	13	130	74	
Yearly savings (US$)	-	210.00	-	210.00

The calculated savings are based on the Dutch Average repair costs

Global Out of Stock Period: 254 years
Global Serviceable Stock value: $ 642 712.07
Global yearly demand value: $ 2 871.68

121873068

	BE	GY	NE	total
Repairable Y/N	N	Y	N	
Average Replacement per year:	0	396	69	465
Scrapped items	-	0	0	1
Average repair costs (US$)	-	?	-	
Procurement Lead Times (wks)	35	130	74	
Yearly savings (US$)	-	?	-	-

The yearly saving can not be calculated, no information about repair prices is available

Global Out of Stock Period: 12.1 years
Global Serviceable Stock value: $ 161 427.20
Global yearly demand value: $ 13 401.66

121431077

	BE	GY	NE	total
Repairable Y/N	N	N	Y	
Average Replacement per year:	41	16	1	58
Scrapped items	-	-	0	1
Average repair costs (US$)	-	-	?	
Procurement Lead Times (wks)	35	69	108	
Yearly savings (US$)	-	-	?	

Global Out of Stock Period: 26.2 years
Global Serviceable Stock value: $ 1 009 857.16
Global yearly demand value: $ 40 145.42

121428179

	BE	GY	NE	total
Repairable Y/N	N	N	Y	
Average Replacement per year:	1	39	3	43
Scrapped items	-	-	0	0
Average repair costs (US$)	-	-	?	
Procurement Lead Times (wks)	17	69	104	
Yearly savings (US$)	-	-	?	?

Global Out of Stock Period: 13.2 years
Global Serviceable Stock value: $ 142 496.38
Global yearly demand value: $ 17 633.21

Item 5 - 10 year in stock (3 items);

121405395

	BE	GY	NE	total
Repairable Y/N	Y	Y	N	
Average Replacement per year:	0	61	2	63
Scrapped items	-	13	-	13
Average repair costs (US$)	?	92.32	-	
Procurement Lead Times (wks)	30	78	65	
Yearly savings (US$)	-	4431.36	-	4431.36

Global Out of Stock Period: 7.0 years
Global Serviceable Stock value: $ 1 287 858.22
Global yearly demand value: $ 220 616.84

005370372

	BE	GY	NE	total
Repairable Y/N	Y	N	Y	
Average Replacement per year:	0	22	1	23
Scrapped items	0	-	7	7
Average repair costs (US$)	396.59	-	550.00	
Procurement Lead Times (wks)	43	39	26	
Yearly savings (US$)	-	-	-	-

Global Out of Stock Period: 9.2 years
Global Serviceable Stock value: $ 214 542.97
Global yearly demand value: $ 16 939.10

121455960

	BE	GY	NE	total
Repairable Y/N	N	Y	N	
Average Replacement per year:	0	12	3	15
Scrapped items	-	0	0	0
Average repair costs (US$)	-	?	-	
Procurement Lead Times (wks)	26	130	61	
Yearly savings (US$)	-	?	-	?

Global Out of Stock Period: 6.7 years
Global Serviceable Stock value: $ 20 913.72
Global yearly demand value: $ 3 211.23

Step 2: Comparison of repair and procurement parameters, Item by item discussion

Remark: The repair times given by BE for consumable item are repair times if the item should be a repairable item.

008949533	BE	GY	NE
PLT	61	39	43
ART	41	54	12
PP	4 361.13	55 302.16	74 210.53
ARC	9 284.59	0	706.80
PLT/ART	1.48	0.72	3.58
PP/ARC	0.47	0	105.00
repairable Y/N	Y	Y	Y

Analysing the data given by the armed forces, is expect that some mistakes must have been arisen. Because of the enormous differences in the parameters, specially the procurement price and average repair costs, no valid conclusion can be drawn. Also in a next step, the same problem will arise. Further research in this item makes no sense with this data.
No further research.

121675887	BE	GY	NE
PLT	17	52	104
ART	12	22	?
PP	355.14	335.33	376.32
ARC	178.38	199.03	?
PLT/ART	1.42	2.36	?
PP/ARC	1.99	1.68	?
repairable Y/N	Y	Y	Y

More detailed researched is required. The decision process of this item will be continued.
Further research.

121430186	BE	GY	NE
PLT	26	130	65
ART	39	29	?
PP	4903.91	4619.01	5184.21
ARC	1648.51	425.87	?
PLT/ART	0.67	4.48	?
PP/ARC	2.97	10.85	?
repairable Y/N	Y	Y	Y

Considering the data from GY, the item will be considered as repairable item because of the high values of the ratio's. To take a decision for BE, more information is needed about the scrap rate.
Further research.

121456305	BE	GY	NE
PLT	48	117	69
ART	12	29	?
PP	541.45	510.00	573.68
ARC	209.22	382.96	?
PLT/ART	4.00	4.03	?
PP/ARC	2.58	1.33	?
repairable Y/N	Y	Y	Y

The values of the parameters are not extremely different. Also the values of the ratio's are not extreme enough to draw a conclusion without more information. **Further research.**

006799643	BE	GY	NE
PLT	26	39	39
ART	38	26	-
PP	299.72	456.46	434.21
ARC	108.11	3.70	-
PLT/ART	0.68	4.48	-
PP/ARC	2.97	10.85	-
repairable Y/N	Y	Y	N

Comparing the ARC, this is such a big difference that further research will lead to invalid conclusions. **No further research.**

009999842	BE	GY	NE
PLT	69	?	30
ART	41	-	-
PP	37.99	31.86	16.32
ARC	186.49	-	-
PLT/ART	1.68	-	-
PP/ARC	0.20	-	-
repairable Y/N	Y	N	N

The reason that BE still consider this item as a repairable item, could be the relative high (for BE) procurement lead time. Comparing this PLT to the PLT of NE, it could be shorter. Also if we look to the ratio, the repair price is about five times the procurement price. Conclusion: this item will be considered as **consumable item**.

121771825	BE	GY	NE
PLT	39	130	65
ART	41	37	-
PP	136.86	132.45	147.37
ARC	202.70	34.84	-
PLT/ART	0.95	3.51	-
PP/ARC	0.68	3.80	-
repairable Y/N	Y	Y	N

Remarkable is the data from BE. This item is considered as repairable item in BE, but both ratio's are below 1. What means that the ARC are higher than the PP and also the ART is longer than the PLT. For GY it is understandable that this item is considered as repairable item. A decision made on the data from GY, the item will be considered as **repairable item**.

000156669	BE	GY	NE
PLT	43	13	13
ART	41	-	?
PP	355.79	888.91	486.84
ARC	0	-	?
PLT/ART	1.04	-	?
PP/ARC	0	-	?
repairable Y/N	Y	N	Y

Not enough an confident data available. **No further research**.

121429961	BE	GY	NE
PLT	22	78	22
ART	12	-	-
PP	710.87	679.77	1031.58
ARC	0	-	-
PLT/ART	1.83	-	-
PP/ARC	0	-	-
repairable Y/N	Y	N	N

Not enough confident data available. **No further research**.

121455794	BE	GY	NE
PLT	30	?	104
ART	41	-	-
PP	997.23	1064.53	1052.63
ARC	72.92	-	-
PLT/ART	0.73	-	-
PP/ARC	13.66	-	-
repairable Y/N	Y	N	N

Because of the high PP/ARC, this items will be researched in more detail. **Further research**.

009992122	BE	GY	NE
PLT	43	13	13
ART	41	0	?
PP	209.99	251.72	386.84
ARC	-	?	?
PLT/ART	1.05	?	?
PP/ARC	-	0	?
repairable Y/N	N	Y	Y

Not enough confident data available. **No further research**.

121719741	BE	GY	NE
PLT	22	61	65
ART	12	20	-
PP	143.58	137.43	155.26
ARC	-	6.30	-
PLT/ART	1.83	3.05	-
PP/ARC	-	21.81	-
repairable Y/N	N	Y	N

Based on the German data, the item should be considered as repairable item. But if we assume that GY could provide the item with the same PLT as BE, the decision will be depended on the scrap rate and demand figures. **Further research.**

007279884	BE	GY	NE
PLT	43	39	30
ART	39	-	?
PP	375.50	311.51	407.89
ARC	-	-	?
PLT/ART	1.10	-	?
PP/ARC	-	-	?
repairable Y/N	N	N	Y

Not enough confident data available. **No further research**.

Step 3: Cost Analyses
Item by item discussion

NSN: 121675887

BE : Replacements the last 5 quarters; scrap rate 0, ARP = \$178.38; PP = \$ 355.14
$E_{cons}(Cost) - E_{rep}(Cost) = Q \cdot 1 \cdot (355.14 - 178.38)$

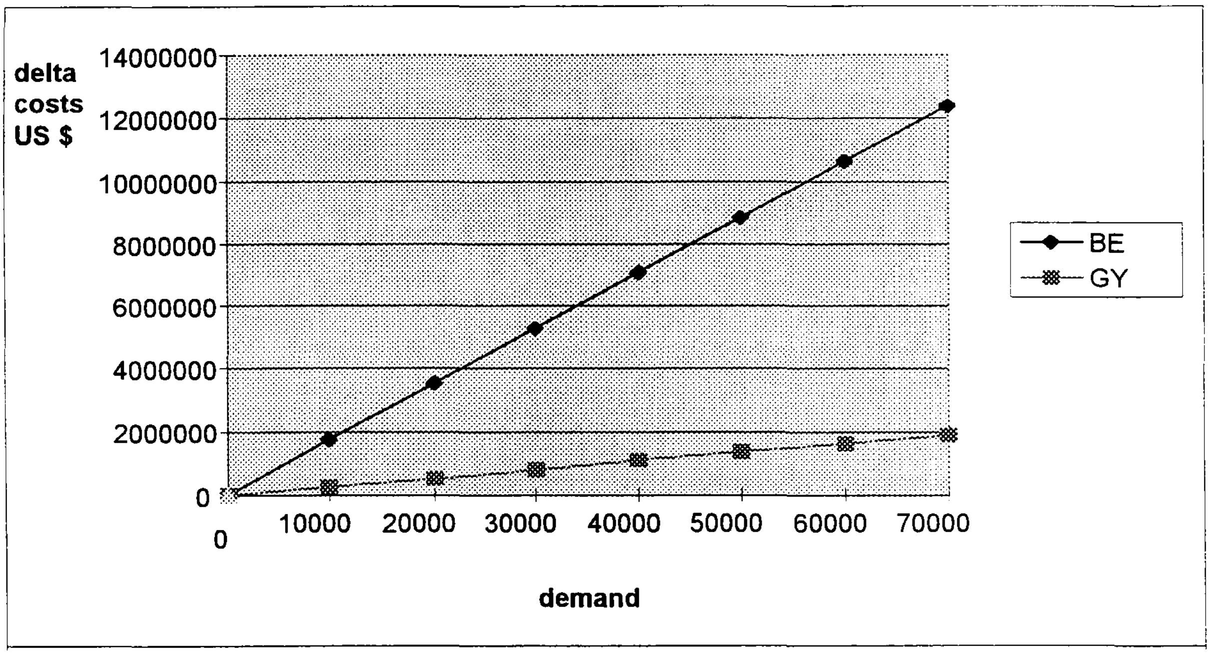
GY : Replacements the last 2 years, scrap rate 80%; ARP = \$199.03; PP = \$ 335.33
$E_{cons}(Cost) - E_{rep}(Cost) = Q \cdot 0.2 \cdot (335.33 - 199.03)$

NE : No replacements the last two years and no information about ART and ARC are available.

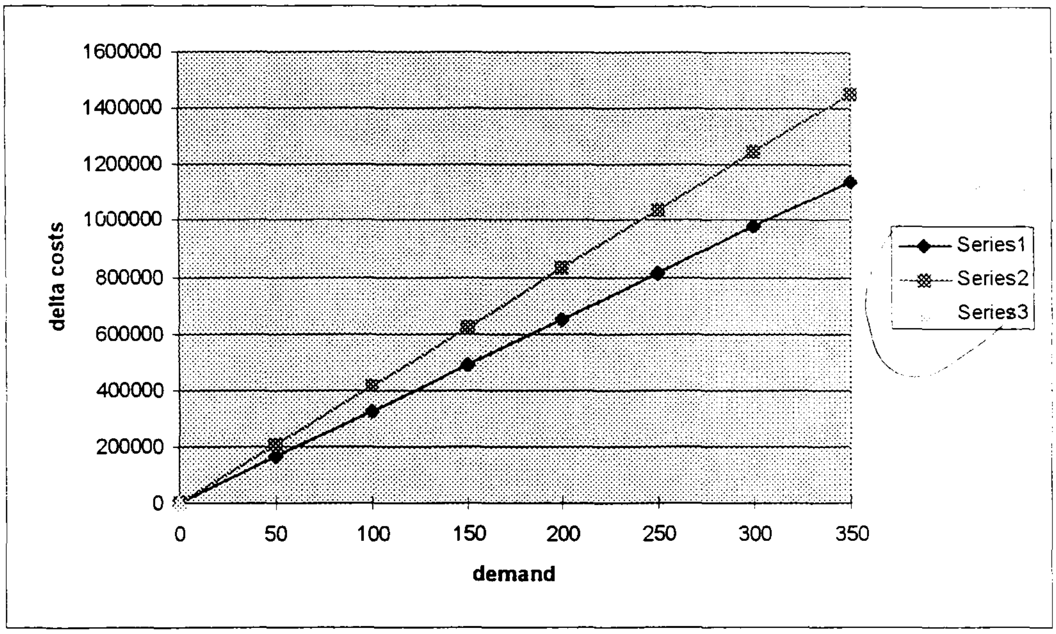
This item is considered as a repairable item in BE, GY and NE. The formulas for BE and GY are drawn in the graph below. The graph shows the difference in costs if the item is considered as repairable or consumable item drawn against the demand. Serie one is based on the data from BE and serie 2 on the data of GY.

Based on the BE data:
The Belgium Armed Force has a yearly demand of almost 7000 items. This means if the fixed costs per year arisen from the repair facilities are higher than \$ 1 237 320.00, the item can better be considered as consumable item. Compared to the data from GY;
individually

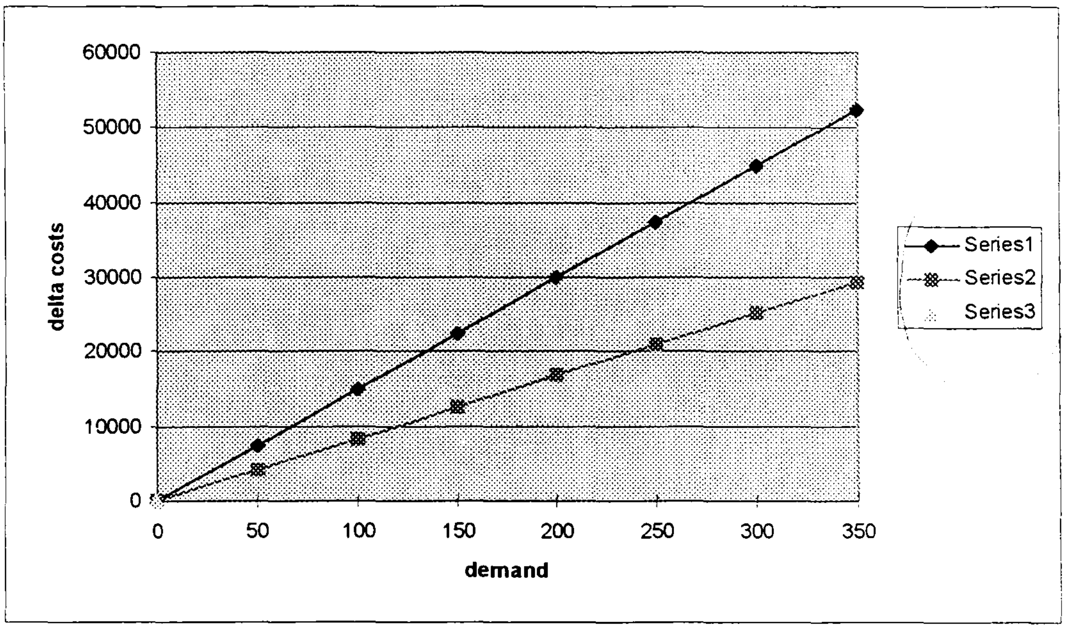
Yearly demand:	BE:	6968
	GY:	32725
	NE:	0



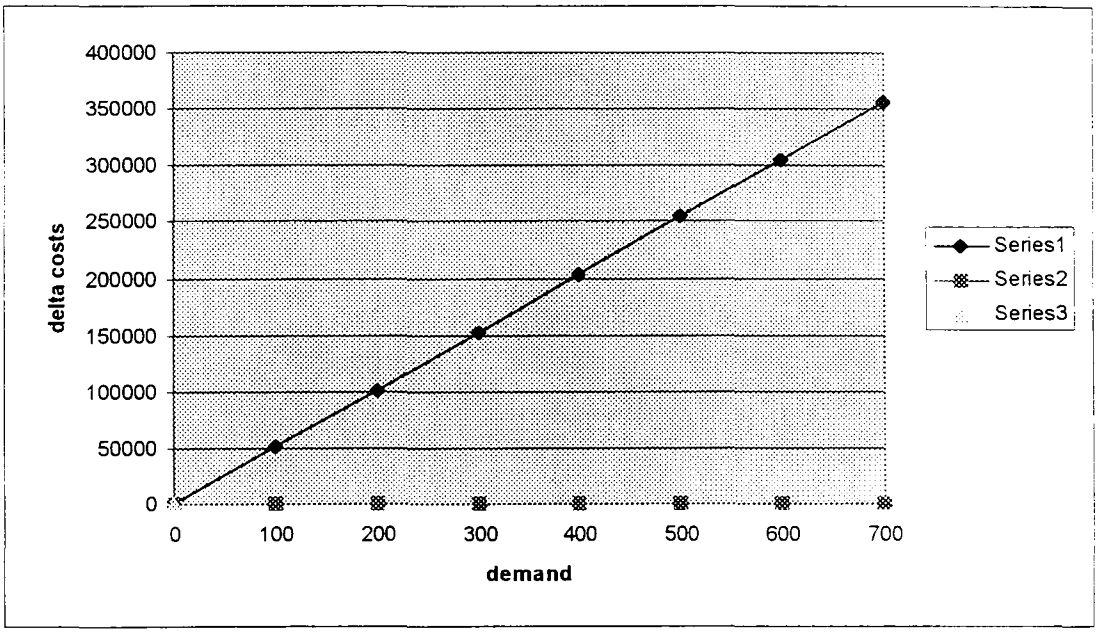
NSN: 121430186
BE : No replacements the last 5 quarters; scrap rate ?, ARP = $ 1 648.51; PP = $ 4903.91
GY : Replacements the last 2 years, scrap rate 1%; ARP = $ 425.87; PP = $ 4 619.01
NE : Replacements the last 2 years, scrap rate 0%; ARP = $?; PP = $ 5184.21
Yearly demand: BE 0; GY 148; NE 13



NSN: 121456305
BE : Replacements the last 5 quarters; scrap rate 55%; ATC $ 209.22; PP = $ 541.45.
GY : Replacements the last 2 years, scrap rate 34%; ARP = $ 382.96; PP = $ 510.00.
NE : Replacements the last 2 years, scrap rate 0%; ARP = $?; PP = $ 573.68
Yearly demand: BE 7; GY 115; NE 15



NSN: 121455794
BE : Replacements the last 5 quarters; scrap rate 45%; ATC $ 72.97; PP = $ 997.23.
GY : Replacements the last 2 years; CI; PP = $ 1064.53.
NE : Replacements the last 2 years, CI; PP = $ 1052.63.
Yearly demand: BE 139; GY 388; NE 6



NSN: 121719741
BE : Replacements the last 5 quarters; CI; PP = $ 143.58.
GY : Replacements the last 2 years; Scrap rate 1%; ARC = $6.30; PP = $ 137.43.
NE : Replacements the last 2 years, CI; PP = $ 155.26
Yearly demand: BE 273; GY 3860; NE 257