TAMPERE POLYTECHNIC

INTERNATIONAL BUSINESS

FINAL THESIS

# INCORRECT MATERIAL MOVEMENTS IN WÄRTSILÄ DCV
## The SAP Point of View

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**ABSTRACT**

This thesis was made for Wärtsilä Finland Oy Delivery Centre Vaasa (DCV). The main goal of the research was to find out the reasons and sources for incorrect material movements in the ERP system SAP R/3 and to present development suggestions in order to reduce the incorrect movements.

The theoretical part of this study deals with materials handling, especially from the viewpoint of effective warehouse operation. Other issues addressed in the theoretical part consist of warehouse management, goods reception, the Just-in-Time approach to production and Material Requirements Planning.

The problems related to the incorrect material movements are specified and presented in the present situation description. A description of the processes where material movements are involved is also included in the section.

The analysis and findings chapter contains the analysis of the sources of the material movement problems. Finally solution suggestions are present for the problems found.

Enhancing the situation of the incorrect goods movement list is an ongoing process in DCV. The solution suggestions of this thesis will be carried out at least partly, but no definite time scale can be presented.

**Key words:** Materials handling, material movements, warehouse management, SAP Materials Management Module

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# Abbreviations and Key Concepts

| | |
|---|---|
| BOM | Bill of Materials, product structure |
| COGI-list | A list of goods movements with errors in SAP |
| DCV | Delivery Centre Vaasa, the Wärtsilä delivery unit in Vaasa City |
| EBOM | Engineering Bill of Materials, planning structure |
| ERP | Enterprise Resource Planning |
| IM warehouse | Warehouse in which only a non-specific location for materials is defined |
| MPS | Master Production Schedule, one of the MRP inputs |
| MRP | Materials Requirements Planning, determines how much material to purchase and when to purchase it |
| MRP Profile | A code that determines the material directing parameters |
| PBOM | Production Bill of Materials, made by production planning based on the EBOM |
| Pre-order | Purchase order for materials that require home-calling |
| Project Stock | Stock of materials that are assigned for a certain project |
| W20 | W20 Product Factory of DCV |
| W32 | W32 Product Factory of DCV |
| WBS-element | Work Breakdown Structure, project identification code used in Wärtsilä project management |
| WM warehouse | Warehouse in which materials have very specific, detailed locations |

# 1 Introduction

## 1.1 Background

Ever since the introduction of the ERP-system SAP R/3 in the beginning of 2004 the erroneous materials movements in the system have been a problem in DCV. Materials continuously end up in the error list for the wrong reasons. The reasons for this vary; incorrect or inadequate reporting of goods reception, missing or incorrect storage locations of materials, missing prices for materials, and so on. As a result the error list always has a mass of materials on it. Solutions for material movement problems are called for. Therefore the reasons of the problem needed to be researched and alternative ways of working identified.

The selection of the subject was done in cooperation with the logistics department and Delivery Development Centre people. The aim was for the thesis topic to answer to the most urgent needs of the company, as well as to suit my field of study and interests. The entire time of writing the thesis I was working in Wärtsilä, in Delivery Centre Vaasa. The background work, research, and writing were done there.

## 1.2 Research Problem and Thesis Objectives

The scope of this thesis is the improvement of the Delivery Centre Vaasa in-house logistics process. The research problem is to analyse and develop material movement reporting in the ERP-system. The intended outputs of the thesis are a wide-ranging overview of the current problems of the material movements in the ERP-system and a proposal of a new way of working related to these problems.

In order to achieve this objective it is necessary to concentrate on the following tasks:

- Define and study current operative process related to material movements in the ERP-system
- Analyse reasons and sources for incorrect movements from different perspectives
- Present development suggestions and measures in order to reduce incorrect material movements

In addition to this material controlling methods and master data maintenance procedures need to be addressed as they are closely related to current material movement problems in the ERP-system.

## 1.3 Research method

The research method used in this thesis is action research. It is a research method in which the researcher intervenes in the activities of a community. By his or her intervention the researcher changes these activities and at the same time conducts the research. The goal is to improve the activities, strategies, practices, and knowledge about the environment within which the community works.

The role of the researcher is to identify the hidden characteristics behind the routines that the community has developed. This is easier for a third party; the researcher coming from outside the community. Once the characteristics behind the routines have been recognized, it is possible to develop alternative ways of working, ones that are more effective than the preceding ways. Action research could be described as participative observation. As the nature of the research method requires, I was working in the logistics department of Wärtsilä DCV during the entire process of writing the thesis.

# 2 Company Overview

## 2.1 Wärtsilä Oyj Abp

Wärtsilä is a supplier for builders, owners, and operators of vessels and offshore installations. The company has a global service network that aims to take complete care of the customers' ship machinery at every lifecycle stage. In summary, Wärtsilä is the leading global ship power supplier and a major provider of solutions for decentralized power generation and of supporting services (Power on Land and at Sea, 2002 and Wärtsilä in Brief, 2004).

Since May 2005 Imatra Steel has been a part of a new company Oy Ovako Ab. Wärtsilä has holdings of 26,5% in Ovako (Wärtsilä Internet, 2006).

Wärtsilä has 130 offices globally and is present in more than 60 countries of the world. The company currently employs a little over 12 000 people worldwide. The net sales in the financial year 2005 were 2,638.8 million euros and the operating income 224.3 million euros (Wärtsilä Internet, 2006 and Company statement, 2006).

The core business operations of Wärtsilä consist of Ship Power, Service, and Power Plants, which together form the Power Divisions:

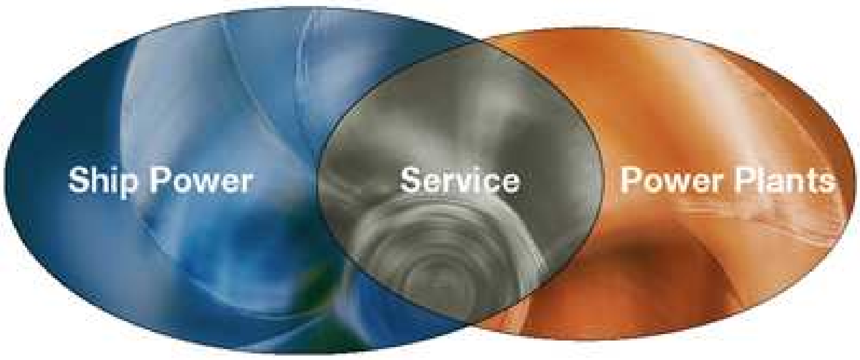


**Figure 1.Wärtsilä Group Structure (Wärtsilä Internet, 2006)**

Power Plants supplies decentralized power plant solutions, along with operation and maintenance services. Ship power is a global ship power and service provider. Service interlinks these two businesses by supporting Wärtsilä customers all the way through the lifecycle of their installation (Wärtsilä intranet, 2006).

## 2.2 Wärtsilä Finland Oy

Wärtsilä Finland operates in four locations: In Vaasa city, in Runsor in Vaasa, in Turku, and in Raisio. In Vaasa city operates the Delivery Centre Vaasa, Engine R&D, Finance, and HR. Service, Power Plants, Ship Power, Marketing, and Legal departments are located in Runsor. The Turku and Raisio offices are much smaller than Vaasa with only 230 employees. Service, WLSA Training Centre, Engine R&D, HR, and Ship Power Solutions are located there. Engines were previously manufactured in Turku as well but the production was brought down and discontinued at the end of 2004 (Wärtsilä intranet, 2006).

Wärtsilä Finland employed 2109 people in 2005. Wärtsilä Finland is the group’s biggest production unit (Wärtsilä intranet, 2006).

## 2.3 Wärtsilä in Vaasa

The products manufactured in the Vaasa plant are Wärtsilä 20, Wärtsilä 32, and Wärtsilä 34SG. In 2004 Vaasa Factory produced 456 engines. Wärtsilä employs 2000 people in Vaasa.

The factory is located next to Onkilahti, very close to the city centre (Figure 2.). The industrial activities of the area date back to 1894 when the Machine Shop of Onkilahti (Metvikens Mekaniska Verkstad) was founded. Wärtsilä Group acquired the machine shop in 1936 (Wärtsilä intranet, 2006).

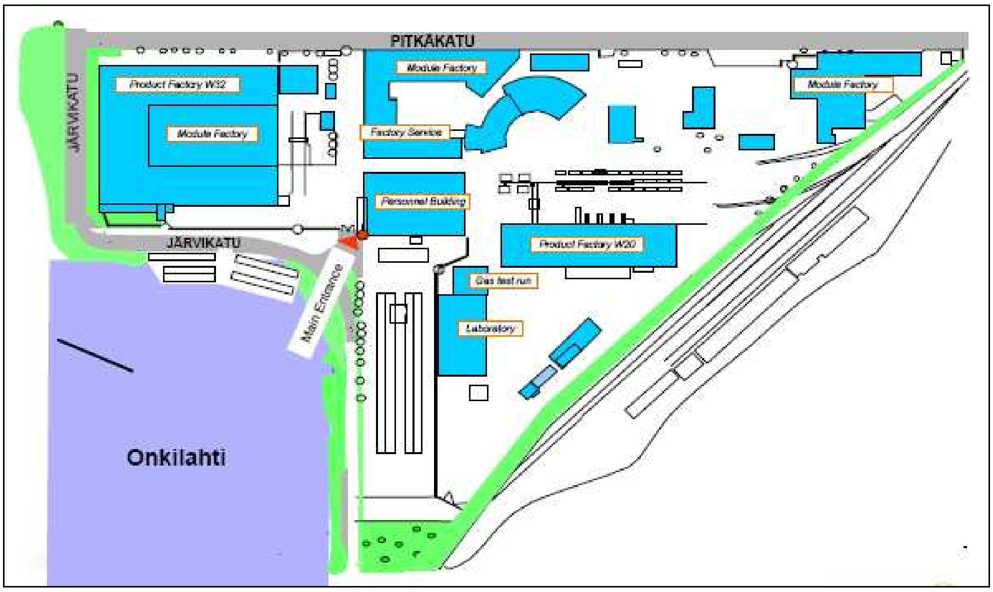


**Figure 2.Delivery Centre Vaasa area**

The picture below illustrates the flow of production in Delivery Centre Vaasa. Engines are produced in two different plants: W20 and W32 factories. The module factory produces modules for both W20 and W32 plants. The module factory consists of four workshops: conrod workshop, cover workshop, part workshop, and cylinder head workshop. The selling divisions sell the products from W32 and W20 product factories.

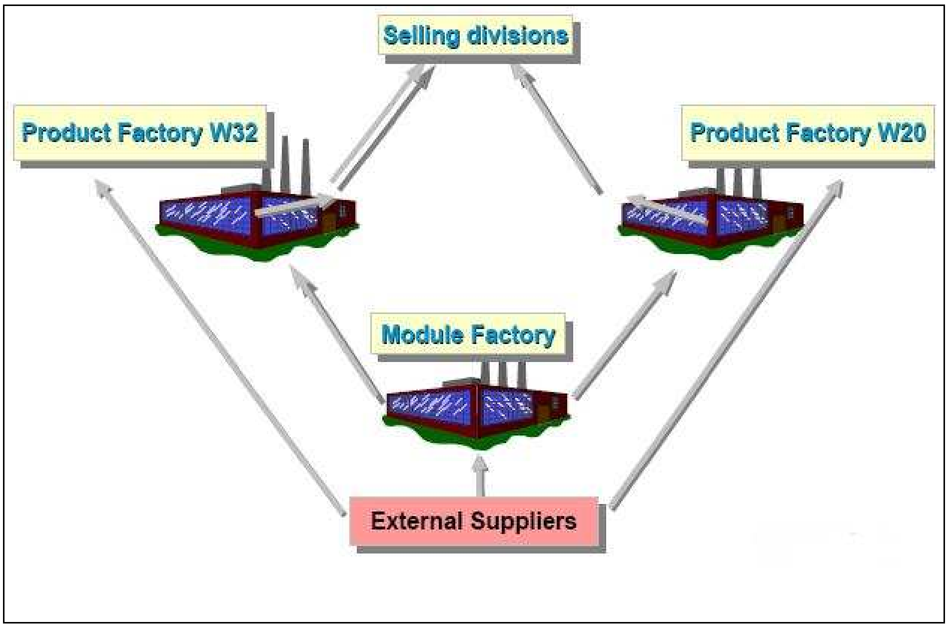


**Figure 3.Production flow in Delivery Centre Vaasa**

# 3 Theoretical Background

## 3.1 Materials Handling

According to Coyle, Bardi, and Langley (1996: 45) materials handling is crucial to effective warehouse operation. Materials handling is also in a very important role in getting goods to customers at the agreed time and in the correct quantities (Coyle 1996: 290). Handling material constitutes a substantial share of the manufacturing, distributing, and marketing costs. Costs incur every single time material is handled. However, the value of a product is not increased by movement or control, therefore handling operations should be minimized. (Tersine 1985: 382)

As Tersine states (1985: 407) appropriately designed and implemented materials handling system will have many positive effects: cost reduction, waist reduction, production capacity increase, and improvements in working conditions and in distribution.

### 3.1.1 Definition and Dimensions of Materials Handling

Materials handling as a term is not an easy one to define. According to Coyle it is most convenient to see materials handling as

"*Efficient short-distant movement that usually takes place within the confines of a building such as a plant or a warehouse and between a building and a transportation agency*".

In modern logistics systems this short-distance movement is usually performed by specially designed equipment. Nevertheless, manual movement is materials handling as well. In most of the present-day companies a combination of elaborate mechanical equipment and manual labour forms materials handling. (Coyle 1996: 284)

A more broad definition states that materials handling is concerned with all aspects of the flow of material within a company. In this view the domain of materials handling is seen to be the transportation of materials from receiving areas through production operations to final shipment to customers. This means that materials handling consists of activities of receiving, storing, transporting, and delivering materials. In brief, handling, storage, and control of materials can be considered as the main components of materials handling. (Tersine 1985: 382)

### 3.1.2 General Objectives of Materials Handling

Materials handling is largely viewed as a cost-absorbing activity. This has its impacts on materials handling objectives. The materials handling objectives are thus cost-centered; they aim at decreasing handling costs and increasing space utilization. (Ballou 1992: 253) Tersine has defined five very basic objectives according to the following table:

| |
|---|
| 1. To eliminate handling wherever possible. |
| 2. To minimize travel distance. |
| 3. To minimize goods in process. |
| 4. To provide uniform flow free of bottlenecks. |
| 5. To minimize losses from waste. |

**Table 1.Objectives of materials handling (Tersine 1985)**

Although these principles were defined over twenty years ago, they can still be considered up-to-date, with some additions and extensions from other sources.

A crucial part of the first objective is to decrease the number of times a company handles goods. When goods are received they need to be moved and located in a storage area. Then goods are moved to an order selection area to be picked and made into orders. Finally, the goods are moved to prepare them to be shipped to customers. There are several movements in these processes that can not be eliminated. Companies should still make sure that goods are not handled several times in each area. In short, an effectively designed materials handling system will aim at minimizing movements to, within, and from a warehouse. This will allow a rapid and efficient product flow through the warehouse, which helps in achieving object 4: ensuring a bottleneck-free uniform flow. (Coyle 1996: 286-287)

Another viewpoint to item handling reduction is that every movement is another possibility to damage the product. Each lifting further deteriorates the package making it more vulnerable to extra damage. Reducing handling can thus act as a quality improving factor. (Ackermann 1997: 303)

### 3.1.3 Materials Handling Principles

Over time certain a number of essential truths of materials handling have been found to exist. These principles can be viewed as forming the basis on which material handling expertise can be built (Material Handling Industry of America, 2006). It is necessary to know some guidelines and principles in order to efficiently plan and control materials handling (Coyle 1996: 291). However, when looking at these principles it is useful to remember that principles should only be implemented if and when they fit the situations. Situations are always unique and can not be forced to fit the principles.

(Tersine 1985: 405) In the following table twenty commonly accepted materials handling principles are presented:

| |
|---|
| 1. Planning Principle. Materials handling and storage activities should be planned to maximize overall operating efficiency. |
| 2. Systems Principle. Handling activities should be integrated into a synchronized operations system covering vendor, receiving, storage, production, inspection, packaging, warehousing, shipping, transportation, and customer. |
| 3. **Materials Flow Principle**. The operations sequence and equipment layout should aim to optimize materials flow. |
| 4. **Simplification Principle**. Reducing, eliminating, and combining unnecessary movements or equipment simplifies handling. |
| 5. **Gravity Principle**. When possible, gravity should be utilized to move material. |
| 6. **Space Utilization Principle**. Use the whole building optimally. |
| 7. Unit Size Principle. The unit load quantity, size, or weight should be increased whenever possible. |
| 8. Mechanization Principle. Handling options should be mechanized. |
| 9. Automation Principle. Automation should cover production, handling, and storage functions. |
| 10. **Equipment Selection Principle**. When selecting equipment, all aspects of the material handled need to be considered. |
| 11. **Standardization Principle**. Handling methods, and types and sizes of equipment should be standardized. |
| 12. **Adaptability Principle. U**se methods and equipment that adapt to a variety of tasks and applications, unless special equipment is necessary. |
| 13. Deadweight Principle. The ratio of mobile handling equipment deadweight to payload should be reduced. |
| 14. Utilization Principle. Optimize use of equipment and labour. |
| 15. Maintenance Principle. Plan for preventive maintenance of equipment. |
| 16. Obsolescence Principle. When more efficient methods and equipment are found replace the obsolete ones. |
| 17. Control Principle. Material handling activities that improve control of production, inventory, and order handling should be used. |
| 18. Capacity Principle. Handling equipment used should improve production capacity. |
| 19. Performance Principle. Handling performance efficiency can be determined in terms of cost per unit handled. |
| 20. Safety Principle. Methods and equipment used should be safe. |

**Table 2.Principles of Materials Handling (Coyle 1996)**

Bolded principles are of particular importance.

The simplification principle is one of particular emphasis and aims at reduction of material handling work. However, simplification needs to be done without compromising productivity or the level of service required of the operation. Heragu states that the space utilization principle includes the elimination of jammed aisles and unorganised spaces in work areas. He also suggests balancing the maximization of storage density against accessibility and convenience in storage areas. (Heragu 2006)

Heragu broadens the definition of the standardization principle: “Material handling methods, equipment, controls, and software should be standardized within the limits of achieving overall performance objectives and without sacrificing needed flexibility, modularity and throughput.” In practise, standardization is applicable to for example sizes of containers and operating procedures and equipment. (Heragu 2006)

### 3.1.4 The Effects of Materials Handling Problems

Poor materials handling has many unwanted direct consequences: lost or damaged products, customer dissatisfaction, increased inventory levels, production delays, idle employees and equipment. Of course all of these generate more cost. The emphasis should however be on the company's overall cost. Sometimes increased materials handling costs can have the opposite effect on the company's overall cost: they may actually be reduced. (Tersine 1985: 382)

Unsatisfactory materials handling can have a negative impact on the customer's order cycle time. Therefore, if materials handling is not effectively taken care of it can cause deterioration of customer service. (Ballou 1992: 253)

### 3.1.5 Materials Handling Functions Within Storage-Handling Systems

Within storage-handling systems the activities of materials handling are the three primary ones: loading and unloading, movement to and from storage, and order filling. (Ballou 1992: 244)

Loading and unloading can be thought as the beginning and the end of the chain of events that form materials handling. The goods need to be offloaded from the transportation equipment when they arrive at the receiving warehouse. In some cases the unloading and the movement to storage are best handled as one operation. Sometimes this is not possible, for example some goods require sorting, quality inspections, or classifying. Also the equipment used for unloading and movement to storage can be different. (Ballou 1992: 244)

Loading is similar to unloading but activities take place in a reverse order. Also additional activities are required at the loading point. Again, an inspection may be required before the goods can be loaded to the transportation equipment. Loading may sometimes require extra activities that aim at damage prevention, such as strapping and packaging the load. (Ballou 1992: 244)

Goods might be moved several times after the unloading. First they need to be moved to the storage location. The possible use of a special picking area creates some extra movement. (Ballou 1992: 244)

Picking or more formally, order filling is the activity of selecting stock from the storage locations (or the separate order-picking area) according to the sales orders. According to Ballou order-picking is the most critical of all the materials handling activities. This is because the handling of small-volume orders is labour-intensive and therefore relatively more costly than the other activities. (Ballou 1992: 245)

## 3.2 Warehouse Management

According to Ackerman (1997: 13) warehousing essentially provides time and place utility for any product, with the help of well-organized management of space and time. The general functions of warehousing can be defined to be:

- Stockpiling
- Product mixing
- Consolidation
- Distribution
- Customer satisfaction (Ackerman 1997: 13)

### 3.2.1 Goods Reception

The goods reception department is in charge of the tasks related to receiving goods. These tasks include the physical handling of incoming shipments, the identification of such material, the verification of quantities, the preparation of reports, and the routing of the materials to the locations where they are stored or used. Receiving and purchasing are closely related. Therefore the work of the receiving and purchasing departments is typically directly or indirectly linked. (Leenders 1993: 53&89)

For some goods received an inspection is required. With some materials the whole delivery is inspected, with others only a sample is inspected. (Leenders 1993: 91)

Ackerman (1997: 405-407) has described eleven steps that typically form a goods reception procedure. Not all the steps materialize in all goods reception situations, but all of them should be considered when planning the receiving process. The steps are:

1) Inbound trucker phones warehouse to get a delivery appointment and gives information about the shipment.
2) Warehouse receiving employee verifies the Advance Shipping Notice (ASN) and compares it to the information given by the inbound trucker.
3) Trucker arrives at the specific receiving door or area.
4) Transporting vehicle is secured at the dock.
5) Seal is inspected and broken in the presence of the carrier representative.

6) Load is inspected and based on the inspection either accepted or refused.
7) Unitized goods are unloaded.
8) Floor loaded or loose goods are unloaded.
9) All unloaded goods are staged for quantity verification and final inspection.
10) Carrier damage is properly disposed.
11) Goods are stored in predetermined locations.

As stated in step one, it is best to do the receiving on a scheduled basis. That means that an unloading time should be assigned for all the deliveries. Many companies doubt their abilities to maintain a scheduled receiving area. Yet, doing the receiving on a scheduled basis has advantages for both the carrier and the receiving company. It enables better ability to predict and control the flow of work. (Ackerman 1997: 406)

After the seal has been broken and the doors of the transporting vehicle opened, an initial inspection takes place. Some companies perform quality tests at this point before initially accepting of refusing the received materials. (Ackerman 1997: 406-407) With some materials the whole delivery is inspected, with others only a sample is inspected. There are also materials that do not require inspection or testing at all. It can also depend on the supplier; if the history of cooperation is long and records show that quality has been excellent, tests and inspection may be considered unnecessary. (Leenders 1993: 91&163)

The last step is very critical in trying to achieve storage efficiency. The decisions about where each material is stored should always be made beforehand, not at the time the material needs to be stowed in the warehouse. The storage location decisions should aim at forming a clear and functional storage pattern. The forklift operator can not be responsible for determining the storage locations; this will result in wasting space since the goods will most likely be left in the quickest and easiest spot. The storage location decisions should be made by management or a storage planner should be assigned. (Ackerman 1997: 407-408)

### 3.2.2 Goods Reception: SAP R/3 Viewpoint

A typical goods reception process consists of certain steps also in SAP. The process starts when the delivery vehicle arrives at the warehouse. At that time the supervisor creates a material movement document in SAP. After that, the system produces a transfer requirement and a quantity posting to the goods reception area. At this point the goods will be unloaded to the goods receipt area. After the unloading the system will generate a transfer order for the received materials. This transfer order assigns the materials to their destination storage bins, which are reserved for those specific materials. The transfer order will usually be printed out or electronically displayed to the goods movement section. (Administering SAP R/3 1998: 160)

After these steps, the materials are ready to be transferred to the storage bins reserved for them. The quantities of the storage bins are checked and confirmed to the system. SAP will then print out the confirmation of the storage bin inspection operation. The confirmation is printed on the transfer order document, which in turn is then confirmed. Finally, the system updates the inventory and stock balances so that the materials are available for consumption or further movement. (Administering SAP R/3 1998: 160)

The SAP transfer order can support five different types of goods receipt (Administering SAP R/3 1998: 160):

1) Goods receipt based on a purchase order.
2) Goods receipt without a reference purchase order.
3) Goods receipt destined for in-house production order.
4) Goods receipt for a batch reserved for inspection.
5) Goods receipt from a customer who is returning goods that are unwanted for some reason.

### 3.2.3 Philosophy of Just-in-Time Approach to Production

According to Meredith (2002: 335) just-in-time (JIT) is best described as a philosophy that aims at eliminating waste of all types. This includes scrap and defective products, excessive inventory levels, unnecessary space, idle resources, and long lead times. Jacobs (2006) states that waste results from activities, that add cost without adding value.

The idea behind the name just-in-time is to replenish material buffers just at the time they are needed – not before, not after. JIT is also sometimes called lean production, stockless production, zero inventories, or even continuous flow. (Meredith 2002: 335) The JIT system works in an ideal way, when the ordered products arrive exactly when the company needs them. This allows no late or early deliveries. (Coyle 1996: 88)

Meredith (2002: 336) defines three primary principles that the philosophy of JIT is based on:

1) Minimizing waste in all forms.
2) Continually improving processes and systems.
3) Maintaining respect for all workers.

The roots of JIT are in Japan, which shows in these principles as well. Because of the very little space and natural resources available in the country, the Japanese have always used their scarce resources very carefully. They have also always been extremely skilled at maximizing the gain from the available resources. In order to achieve maximum gains, the Japanese have diligently avoided wasting materials, space, and labour. (Meredith 2002: 336-337)

More recently the second principle, continuous improvement has been emphasized. Latest JIT applications are not considered as just a method to convert the wasteful production system into a more efficient one. Nowadays the objective of just-in-time is also seen to be producing continuous improvements throughout the system. This way JIT contributes to keeping the company competitive and profitable in the present and in the future. Continuous improvements are also necessary in order to maximize the yield from the available resources. (Meredith 2002: 336-337)

Respect to one another is also a crucial part of the Japanese culture. Therefore the philosophy of JIT includes minimizing status distinctions between management and workers. Therefore managerial treatment is different under JIT. Managers in traditional workshops are distinguished with several status symbols and privileges. According to the JIT approach the differentiated managerial treatment causes alienation of workers. As a result, a competitive atmosphere develops, when the JIT approach encourages a cooperative atmosphere. The respect principle has been referred to as the most important one. (Meredith 2002: 346, 336-337)

### 3.2.4 Just-in-Time and Inventory Control

Table 3 below illustrates how the JIT systems regard the different components and actions of inventory management compared to traditional inventory systems. The most critical differences are addressed in the paragraphs below.

| Factor | Traditional | JIT |
|---|---|---|
| 1. Inventory | Asset | Liability |
| Safety stock | Yes | No |
| 2. Production runs | Long | Short |
| Setup times | Amortize | Minimize |
| Lot sizes | EOQ | 1-for-1 |
| 3. Queues | Eliminate | Necessary |
| 4. Lead times | Tolerate | Shorter |
| 5. Quality inspections | Important parts | 100% process |
| 6. Suppliers/customers | Adversaries | Partners |
| Supply sources | Multiple | Single |
| Employees | Instruct | Involve |

**Table 3.Traditional inventory systems versus JIT systems (Coyle 1996: 89).**

In Japanese manufacturing, inventory is mainly considered a resource sitting idle and therefore wasting money. (Meredith 2006: 347) In traditional inventory systems, inventory is seen as an asset, whereas in just-in-time systems it is seen as a liability. It has been argued that using a JIT system will force the seller to carry the inventory that the buyer held in the past. This is not the purpose however. Successful JIT systems will reduce inventories for seller as well as the buyer. Obviously JIT systems do not encourage the use of safety stock. (Coyle 1996: 89)

The second difference is that JIT systems usually involve shorter production runs than traditional systems. This requires all the manufacturing and production activities, for example the setup to frequently change from one product to the next. Therefore, controlling the costs occurring from the changeovers is crucial in order for the JIT system to succeed. (Coyle 1996: 89) Reducing setup times is related to shorter production runs. Reduced setup times can be achieved through better planning, process redesign, and possibly product redesign. (Jacobs 2006)

Thirdly, just-in-time minimizes the waiting lines. This is possible when the required materials and components are delivered exactly when and where the company needs them. For example, when manufacturing cars, the parts should be delivered to that part of the assembly line where they are installed into the cars, just before the moment when they are installed. (Coyle 1996: 89)

The fourth differentiating factor is the length of the lead times for both production and deliveries. Short and consistent lead times satisfy the inventory needs in a more timely way. Reduced lead times are enabled by ordering very small lots. (Coyle 1996: 88-90) Ordering small lots will usually require more frequent deliveries. This might increase the delivery costs. It may also sometimes be required for the suppliers to be located closer to the factory than before using the JIT system. (Jacobs 2006)

Fifth, quality is a significant factor when trying to make the JIT-based system to successful. The just-in-time systems are extremely dependant on the good quality of the incoming materials and parts. Also the inbound logistics operations must be of exceptionally high quality. The outstanding quality of materials and operations is vital since just-in-time synchronizes manufacturing and assembly with well-timed and predictable goods reception. (Coyle 1996: 90)

The sixth difference is the relationship between the company and its suppliers and customers. In JIT systems these relationships are best described as win-win relationships. JIT necessitates a strong commitment from both the seller and buyer. This relationship should emphasize quality and decisions that give both parties the maximum benefit. For example, JIT will not work effectively if companies just push inventory to another supply chain member. Instead, they should together seek to find a solution that allows all the members of the chain to reduce their inventory levels. (Coyle 1996: 90)

### 3.2.5 Just-in-Time and Supply Scheduling

Ballou (1992: 528) presents the definition of just-in-time supply scheduling as follows:

*A philosophy of scheduling where the entire supply channel is synchronized to respond to the requirements of operations or customers.*

Just-in-time supply scheduling is characterized by a close relationship with a few suppliers and transport carriers and sharing the important information with these parties. Just-in-time supply scheduling aims at eliminating all possible uncertainties throughout the entire supply chain. (Ballou 1992: 528) Another important feature of JIT supply scheduling is that it is practical to share it along the supply chain. When one company decides to implement JIT, they will teach their suppliers how to use it. These suppliers can in turn teach their suppliers, and so on, along the supply chain. (Meredith 2002: 260)

Managing the supply chain under a JIT approach is likely to require far more effort than a normal supply-to-inventory relationship. However, benefits usually outweigh the effort, since the channel can be operated with minimum inventory which results in substantial savings and improvements in service. The purpose is that the benefits concern all the parties of the supply chain. (Ballou 1992: 529)

### 3.2.6 Main Benefits of JIT

Some of the direct or indirect benefits are mentioned in the chapters above. Meredith (2002: 351) offers a clear summary by defining the five primary types of benefits:

1) Cost savings
2) Revenue increases
3) Investment savings
4) Workforce improvements
5) Uncovering problems

Cost savings are achieved through reduced scrap, inventories, and overhead, less defects, fewer changes due to customers or engineering, less required space, decreased rework and overall labour hours, and so on. Cost saving are estimated to be as significant as around 20 to 25 percent. The best part about JIT is that it is possible to combine the two first benefits; revenue increases can be achieved whilst saving costs. Revenues increase as a result of better service and quality to the customer. Better margins and higher sales allow a better response to customers' needs. (Meredith 2002: 351)

Investment savings attained through JIT systems are considerable. It has been estimated that JIT systems decrease the need of space with about a third, and still the same capacity can be maintained. The second part of investment saving is formed by the previously described inventory reductions. Thirdly, the volume of work produced increases. The increase may very well be as much as 100 percent. (Meredith 2002: 351)

The last two benefits are the workforce improvements and JIT systems' ability to uncover problems. It has been found that the employees working in JIT companies are more satisfied with their work. They are better trained and prefer the team work that JIT requires. As a result, the work is more productive. (Meredith 2002: 351)

The last benefit is unexpected: JIT allows a greater visibility of problems. Different types of difficulties and previously unnoticed bottlenecks are uncovered when trying to speed up processes and getting rid of all waste. (Meredith 2002: 351)

## 3.3 Material Requirements Planning

Material requirements planning (MRP) is not new as a concept and tool. Computing the schedules and amounts of materials required can be considered as the birth of MRP. MRP has been around for decades but in the recent years it has been advancing with huge leaps. Most companies have used computerized inventory systems for years, but those systems were independent of the scheduling system. Material requirements planning links the inventory system and the scheduling system together. MRP systems today are completely integrated, interactive, and operate in real-time. (Chase 1995: 588)

The implementation rate of MRP systems is high in present-day companies. The popularity of the MRP systems is explained by its logicalness, and simply by the fact that it determines the number of parts, materials, and components needed to produce each item in an easily understandable way. (Chase 1995: 588)

Coyle (1996: 92) has defined the goals of an MRP system to be the following:

1) Assuring the availability of materials, components and products for planned production and for customer delivery.
2) Maintaining the lowest possible inventory level to keep the inventory costs as low as possible.
3) Plan manufacturing activities, delivery schedules, and purchasing activities.

Simply stated, the MRP system fulfils these goals by computing the net requirements for each inventory item, time-phasing them, and determining their proper coverage. (Coyle 1996: 92) How this is done will be addressed in the chapters below.

### 3.3.1 Dependent Demand

Some products have what is said to be independent demand. Such products are for example chocolate cake, cars, and televisions. The demand of independent demand items is not related to the demand of any other items. In practice this means that no product exists that would create demand for cars as such. On the other hand every time there is demand for an automobile, demand for a set of tyres and a steering wheel is created. Thus, the demand of car tyres and steering wheels is *dependent* on the demand for cars. (Meredith 2002: 310)

Independent demand is somewhat random, it is controlled by factors that a single manufacturing plant has no control over (Meredith 2002: 311). Dependent demand is easier to forecast since the demand patterns for parts, materials, and supplies that go into end products are derived from the end product demand (Ballou 1992: 533). This is where MRP programs come into the picture.

MRP calculations are based on dependent demand. From the MRP viewpoint, dependent demand is the demand caused by the demand for a higher level item. (Chase 1995: 588)

### 3.3.2 MRP System Structure

According to Meredith (2002: 316) material requirements planning is a management system for inventory and production. Consequently, the system requires information about both of these. The connection between materials planning and operations scheduling is very close. These two systems can not operate independently from each other. Otherwise the results and outputs will be downright false, or at least outrageously incompetent. (Meredith 2002: 316-317)

The figure below is a simplified illustration of the structure of an ERP system. It shows how an MRP system operates and its key elements.

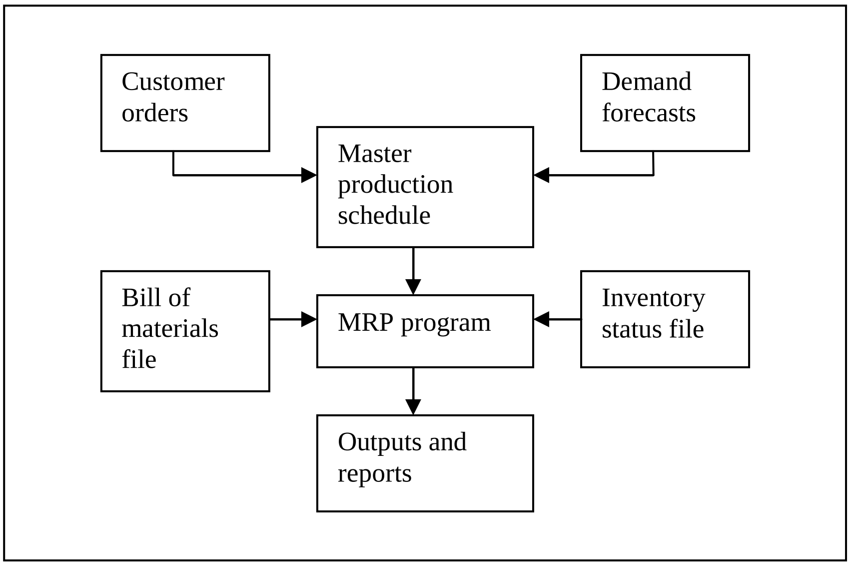


**Figure 4. MRP system structure (Coyle 1996: 93)**

The following description might help to understand the structure of MRP and the functions of the key elements demonstrated in the picture above:

*"MRP is a formal, mechanical method of scheduling whereby the timing of purchases or output from production feeding operations to meet master production schedule requirements is determined from offsetting the requirements by the length of the lead time"(Ballou 1992: 534).*

### 3.3.3 Inputs and Function of Master Production Schedule

Master production schedule (MPS) is the main input to materials requirements planning. As figure 4 states, the MPS is based on customer orders and demand forecasts. The customer orders are records of exactly what each customer has ordered, how many pieces they have ordered and when the ordered goods are required. Sometimes customers change their minds about the orders they have already placed, sometimes even several times. It is important for a company to have the flexibility and ability to react to these customer order changes. This is why MRP is a great help when managing the customer orders. (Slack 2001: 452-453)

The success of many organizations is highly dependent on the accuracy of the demand forecasts. Forecasts of the next few months are most relevant to near-term scheduling and therefore to MRP systems. (Meredith 2002: 233)

According to Coyle (1996: 92) it is the master production schedule that drives the entire MRP system. Meredith (2002: 235) also calls the MPS a blueprint for future operations. The master production schedule contains a statement of the quantities and timing of the end products to be manufactured. The MPS contains all the information about what is assembled, what is manufactured in-house, and what is purchased from suppliers. It is also the foundation of planning the utilization of labour and equipment. (Slack 2001: 454)

The master production schedule is also said to be the driving force behind scheduling. This is because the MPS specifies what end items to be produced in what periods to minimize costs (Meredith 2002: 234-235).

### 3.3.4 MRP Program

It was already stated that the MPS forms the main MRP input. As is visible in figure 4, the other two inputs are the bills of materials and the inventory status file, or as it is sometimes called, the inventory master file.

For each item in the MPS, a bill of materials (BOM) exists. Coyle (1996: 92) compares the BOM to a recipe that specifies the ingredients needed to bake a cake. In a similar way the BOM specifies the amount of raw materials, components, and subassemblies needed to manufacture or assemble the end product. The bill of materials does not simply list the necessary parts; it shows how the finished product is put together from individual items, components and subassemblies. Figure 6 shows a products structure that would create a BOM which is illustrated in table 3.

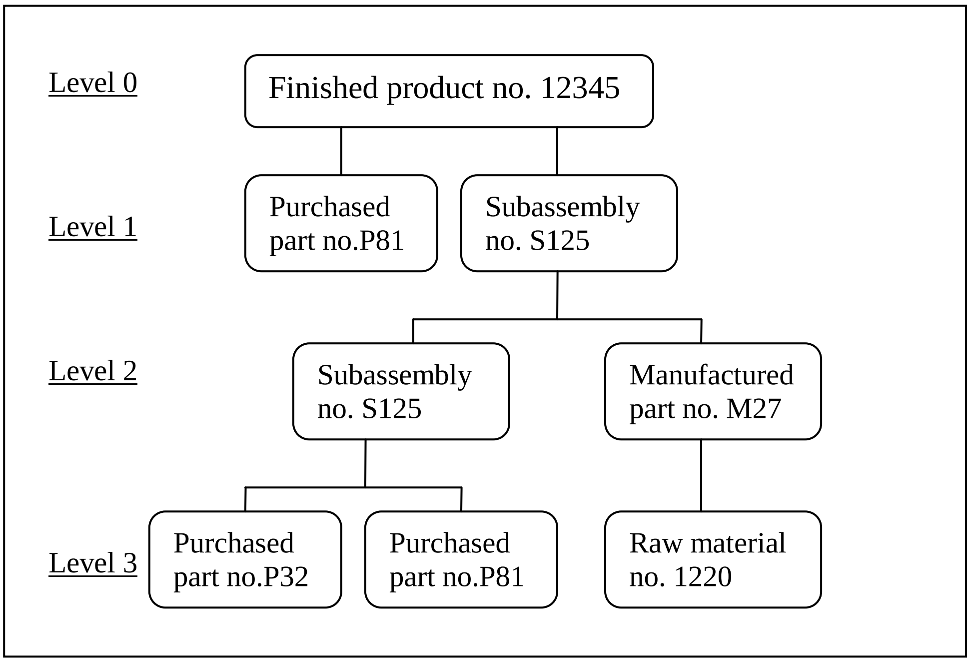


**Figure 5. Product tree structure (Meredith 2002: 317)**

In figure 5, the finished product (also called the parent item) is shown at the highest, zero level. Subassemblies and parts that go directly into the assembly of the parent item are called level 1 components, parts and subassemblies that form level 1 are shown as level 2, and so forth. (Meredith 2002: 318)

| Level 1 Parts | Level 2 Parts | Level 3 Parts | Quantity | Source |
|---|---|---|---|---|
| No. P81 | | | 1 | Purchased |
| No. S125 | | | 1 | Manufactured |
| | No. S225 | | 1 | Manufactured |
| | | No. P32 | 1 | Purchased |
| | | No. P81 | 2 | Purchased |
| | No. M27 | | 1 | Manufactured |
| | | No. 1220 | 3 | Purchased |

**Table 4. BOM for a three-level product (Meredith 2002: 318)**

When a master production schedule shows that there is a requirement for a certain quantity of parent items, production planners will explode the BOM for that parent item. Simply stated, a BOM explosion means

"*stepping down through all its [BOM's] levels and determining the quantity and lead time for each item required to make up the item at that level" (Meredith 2002: 318).*

The outcome of a BOM explosion is information about the volumes, due dates, and necessary order dates of subcomponents. In other words, it states the time-phased requirement for specific quantities of each item necessary to manufacture the parent item. (Meredith 2002: 318)

The inventory status file (ISF) maintains inventory records that enable the MRP program to subtract the amounts on hand from the gross requirements. This way, the net requirements can be identified at any point of time. The inventory status file also holds information about lead times, and the safety stock requirements for certain items. The ISF has a supporting role in maintaining the master production schedule. It is involved in minimizing inventory. (Coyle 1996: 92)

### 3.3.5 MRP System Outputs

The MRP program needs to access the BOM file, the master production schedule, and the inventory records file. Thus, the MRP outputs can take almost any kind of a format and content. There are several ways to group and classify the MRP output reports. Usually they are categorized as primary and secondary reports. (Chase 1995: 600)

Primary reports are the main reports that used most often. They are used for inventory and production control purposes. According to Chase (1996: 600-601) these reports can be for example the following:

1) *Planned orders* that will be released in the future.
2) *Order release notices* that will execute the planned orders.
3) *Due date changes* of open orders that are due to rescheduling.

4) *Cancellations or postponements* of open orders that result from cancellation or postponement of orders in MPS.
5) *Inventory status data*.

The secondary reports are supplementary reports that are optional in the MRP system. Chase (1995: 601) has grouped these reports into three main categories:

1) *Planning reports* which can be used to forecast inventory and specifying requirements over an upcoming time period.
2) *Performance reports* that will point out inactive items and help determine between real-life and programmed lead times, and quantity usage and costs.
3) *Exception reports* that indicate any noteworthy discrepancies, such as errors, late and overdue orders, excessive scrap, or missing parts.

### 3.3.7 Advantages and Shortcomings of MRP

Firms that have implemented MRP systems have found many consequential benefits, both direct and indirect. One of the major ones is reduced inventory which is achieved by maintaining reasonable safety stock volumes, and eliminating redundant inventory. Another major advantage is the MRP's ability to recognize potential problems in processes and in the supply chain before they arise. This way it is possible to correct the problems before they ever take place and cause further problems. (Coyle 1996: 96)

Successful MRP implementation causes reductions in setup and tear-down costs, idle times, and ultimately sales prices. Firms have also noticed an enhancement in the company's ability to respond to market demands. It was also considered beneficial that MRP delays or cancels orders and changes order quantities where necessary, and allows the managers to see the planned schedule before the actual order releases. (Chase 1995: 594-595)

As a consequence of the reduced inventory levels, the firm's ordering and transportation costs sometimes rise. This happens when the company follows the order proposals that suggest the firm order smaller lots but more often (Coyle 1996: 96). Sometimes it is the lack of management commitment that causes failures with the system. It is not always understood that MRP is just a software tool that needs to be used correctly in order for it to work correctly. (Chase 1995: 595)

### 3.3.8 MRP: The SAP R/3 Viewpoint

From the SAP point-of-view, the idea behind MRP is simple. It is making sure you have what you will need, ready to use, before you begin production. (Administering SAP R/3 1998: 118) In the material management context, the main role of MRP is to monitor stocks and automatically produce purchase order suggestions (Administering SAP R/3 1998: 121). For SAP to be able to monitor the stocks - the quantities and values of the materials - it has to be informed about any material movements that take place. These movements can be for example from one storage location to another, or deliveries to customers. The anticipated inventory movements can be controlled by making reservations that identify the material which has been assigned to a particular customer, or to special stock such as project stock. (Administering SAP R/3 1998: 132)

In SAP the key parameters for each material in inventory and their anticipated requirements are the re-order point quantity and the safety stock quantity. These values can be entered into the system manually for single materials, material types, or material groups. The other option is that the system proposes the values for these parameters to the materials controller. The proposals are based on past data and rules that have been coded into the system. The controller can modify these suggested purchase orders before they are released. (Administering SAP R/3 1998: 121)

The task of a material requirements planning run is to create purchase order proposals for materials that have requirement shortages (Administering SAP R/3 1998: 125). SAP fulfils this task by automatically performing the following steps:

- Net requirements calculation
- Lot size calculation
- Scheduling
- Purchase order proposal creation
- Exception message creation

The material reservations and purchase order proposals can be changed manually after the MRP run has been completed if considered necessary (Administering SAP R/3 1998: 122).

# 4. Description of the Present Situation

## 4.1 Material Movement Errors: Background Processes and Affecting Factors

The reasons behind material movement errors in the system can be numerous. This is natural since a countless number of factors affect the flow of materials in the system.

Chapters 4.1.1 and 4.1.2 describe the processes behind the material flows and erroneous material movements. These chapters explain in which stage of the processes the material movement errors take place. The latter part in chapter four concentrates on clarifying why the errors occur: the factors that affect the material flows, and ultimately the various factors behind the material movement errors in the system.

### 4.1.1 Current Process of Order Confirmation and Detection of Erroneous Goods Movements

Appendix 1 is the process chart that illustrates the process of order confirmation and detection of goods movement errors. The process starts when the production planning department creates the Production Bill of Materials (PBOM) based on the Engineering Bill of Materials (EBOM). This initiates a planned order, which in turn creates a material need. The planned order is then transformed into a production order by the production controller in the workshop. This is done in SAP in transactions MD04 and CO41. The production order is then released with the transaction CO02. Here, the system automatically creates a picking list. Next the production order operation is confirmed by the production controller or supervisor in transactions CO11N and CO15.

This is the critical point where it needs to be checked whether some materials went on the goods movements with errors list (COGI list). These could be materials that are consumed from stock or the end product itself. Mostly it concerns only the materials that are consumed from stock. Errors occurring in the consumed materials do not prevent the end product from being completed but it will have two unwanted consequences: the stock balances will become distorted and the costs will not be registered on the production order correctly.

If the production order operation confirmation caused a material to go on the material movements error list, the cause of the problem needs to be found out in the transaction COGI. According to the process chart the detection and correction of erroneous goods movements should be done by the department that caused the error. In practise this happens only some of the time. Usually the material is manually cleared from the error list by SAP key users who are not officially responsible for the operative activities of this kind. After the clearing has been done the stock balances for the cleared materials should be correct and the costs registered correctly on the production order.

In this process the material need, production structure and production order are the inputs. Outputs are the material availability in the stock and the registration of the material cost on the production order.

### 4.1.2 The Engine Manufacturing from a Time Scheme Perspective

In the project of manufacturing an engine, an ExWorks date is defined for the engine. This is the date when the engine is due to be finished. The time of the engine assembly start is determined manually to allow a time buffer. Before the assembly can be started, all the modules needed for it need to be delivered to the assembly site. Therefore SAP – using MRP – calculates backwards the days needed for the module preparation. Of course there are different materials needed for the preparation of these modules. The MRP defines the dates on which the materials are needed to complete the module in time.

At this point SAP needs to calculate the balances of required materials and parts to find out whether there is sufficient stock or whether the stock needs to be replenished by making new purchases. For the materials that need to be purchased the MRP then calculates the date for which it proposes the purchase order to be made. The purchase order date is calculated backwards from the date on which the material is needed. The calculation is made on the basis of the planned delivery time and goods reception processing time. The planned delivery time is the time it takes for the supplier to deliver the goods. A few days of goods reception processing time is added on the planned delivery time. A few weeks – usually two – of safety time is added on the total planned delivery time to make sure the goods really are available at the time they are needed.

The time scheme of engine manufacturing can be illustrated by the following figure:

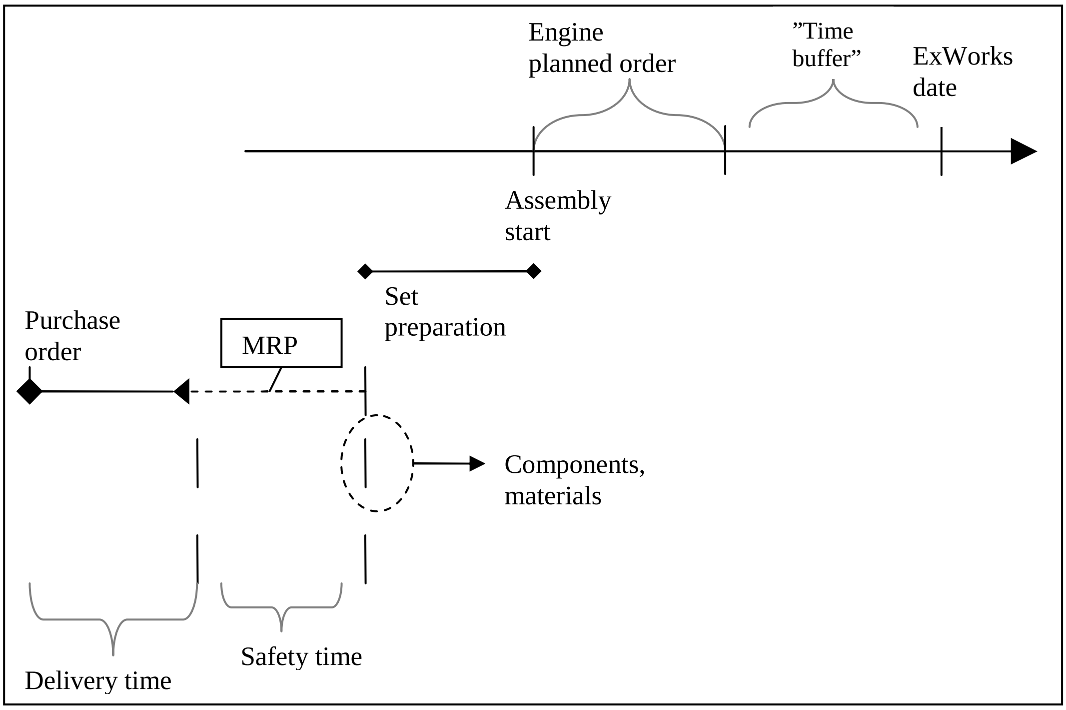

**Figure 6.Engine manufacturing time scheme**

## 4.2 Errors in Different Storage Locations

Material movement errors occur in different storage locations according to the following figures:

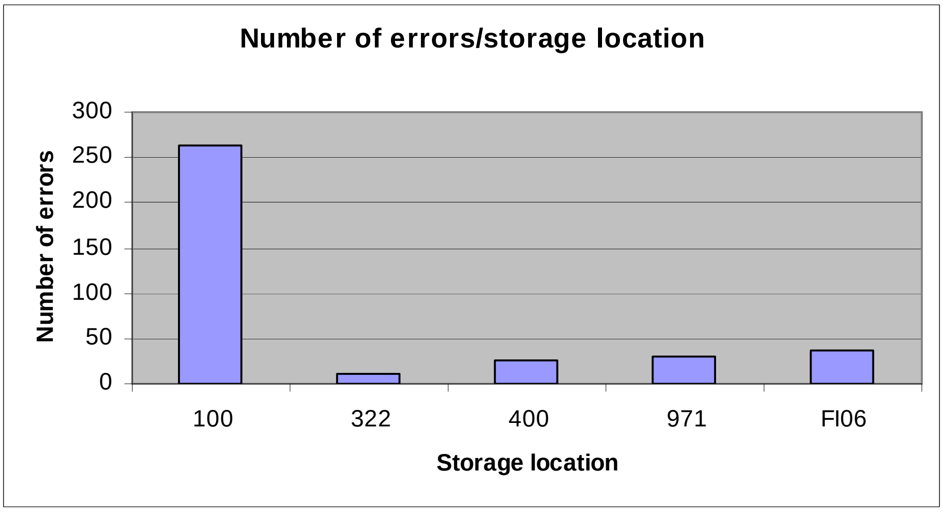

**Figure 7.Number of errors in different storage locations.**

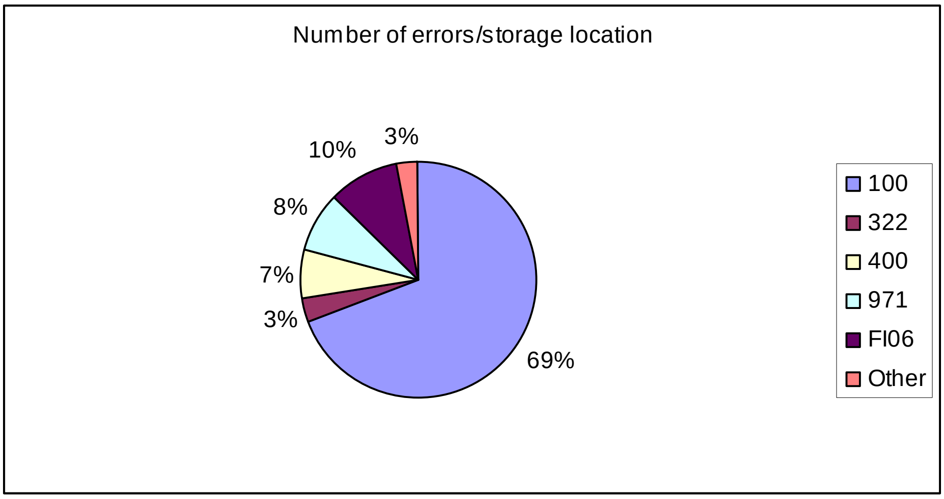


**Figure 8.Percentual shares of errors in different storage locations.**

The storage location codes are defined in SAP as follows:

| | |
|---|---|
| 100 | W32 IM |
| FI06 | W32 WM |
| 971 | W32 IM ABB |
| 400 | Proto manufact. |
| 322 | Cover / IM |

**Table 5.Storage location codes and descriptions in SAP.**

In the WM warehouses materials have very specific locations. It is known precisely on which shelf and in which bin the material is located. The same material can exist in several locations at the same time.

In the IM warehouses only a general storage location is defined. The locations are permanent. If the location of a material was not constant, it would be impossible to track what is where.

The vast majority of errors occur in the storage location 100. Storage location 100 is the large warehouse in the W32 factory. The vast amount of errors in this storage location is partly explained by the size of it. It is natural for the biggest warehouse to have the most problems. Nevertheless, this does not completely explain the mass of errors in the storage location. One explaining factor is that a group of problem materials are stored there. This issue is addressed in chapter 4.3 below.

There are cases in which SAP is trying to consume the material for a project from one storage location, when in fact the material for a certain project is in some other location. Wrong storage location data will cause an error and the material to go on the COGI-list. Storage location 971 seems to be especially prone for this.

## 4.3 Problem Materials

The materials that occur most frequently on the erroneous material movements' list are stated in figure 9 below. These are the materials that have most rows on the error list.

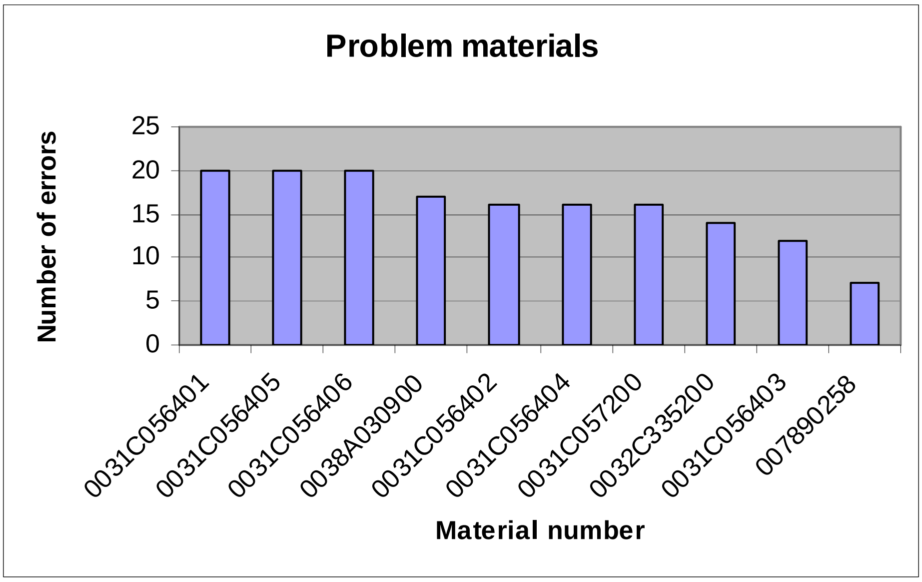


**Figure 9.Most frequently appearing materials on the COGI-list.**

It can be seen that the materials starting with 0031C0 are as majority on the error list. They constitute as much as approximately 25 per cent of all the rows on the error list. The 0031C0-materials are fitted plates for engine fastening. These fitted plates are used in the generator cell. The materials are small in size and somewhat non-valuable. Several of them are used in the assembly of one engine.

The MRP profile of these materials is CO05; they are pre-ordered and require home-calling. The majority of these materials are purchased to and consumed from storage location 100. Some are maintained in storage location 971. These fitted plates are mainly used in the generator cell.

Originally these materials were not pre-ordered, but their MRP profile has been changed in 2004 in order to stop them from piling up in the warehouse. This is the wrong reason to pre-order materials. The main problem now seems to be that the home-calling dates of these materials are not registered in SAP.

Since most of the 0031C-materials are maintained in storage location 100, they greatly constitute to the statistical majority of problems in that location. When the error list is examined for storage location 100 separately, more than 40 per cent of the erroneous materials are 0031C-materials. Obviously if the problems with these materials were fixed, the number of the rows in the error list regarding storage location 100 would significantly decrease.

## 4.4 Most Common Error Codes

Most commonly occurring error codes and their percentual shares are presented in the figure below:

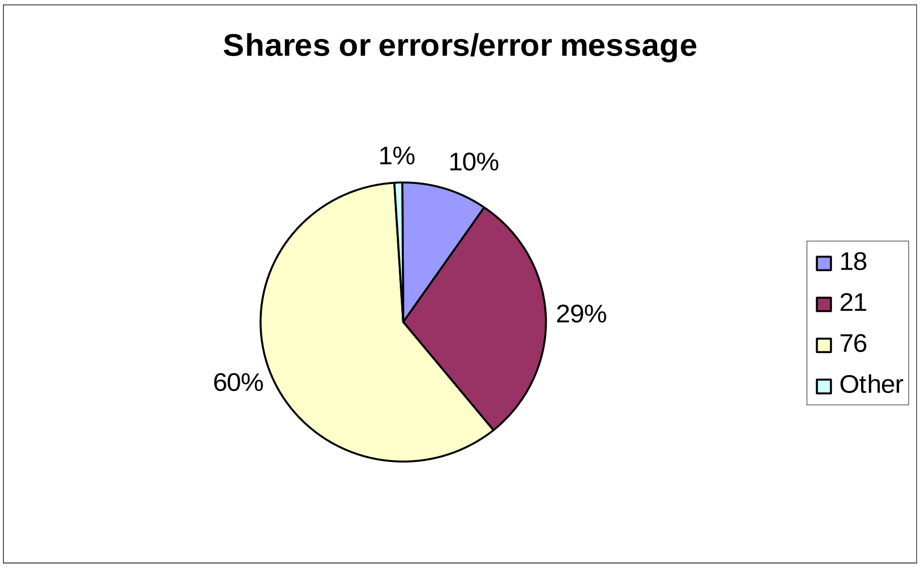


**Figure 10.Most common error codes.**

### 4.4.1 Error Code 076

Almost sixty per cent of all errors have the error code 076. This error message can read in SAP “Special stock 400 Q 00793843 PAAE047075 of this material does not exist”. The number 400 is the storage location from which the system is trying to consume the material, Q indicates that it is a WBS-controlled material, and PAAE047075 is the material number. The other error message for the 076 code is “Deficit of Project stock unr. 1 PC: 0015G166000 FI06 100 Q”. It states the required quantity, material number, plant, the storage location, and the WBS-control. These two messages mean the same thing in practice, and there are four possible situations behind them:

1) There is genuine deficit of these materials or the goods reception reporting has not been done.
2) Materials can be in the wrong storage location in project stock (especially WM-materials).
3) Materials might be in goods reception inspection.
4) Materials produced in-house might not have been confirmed finished in project stock.

Materials with the error code 076 are special stock marked with the letter Q, therefore they are WBS-controlled. WBS-controlled materials are consumed from project stock. It means that they are reserved for a specified project, and from the system point of view they can only be consumed to that project.

WBS-element is an identifier which gives information about the project that the material is assigned to.

### 4.4.2 Error Code 021

Error code 021 gives the error message “Deficit of SL Unrestricted-use 1 PC: 2050G017000 FI06 500”. This message tells the required quantity, material number, plant, and storage location. Five different situations may be the reason behind this message:

1) There is genuine deficit of these materials or the goods reception reporting has not been done.
2) Materials can be in a different storage location than which SAP is trying to consume from (especially WM-materials).
3) Materials might be in goods reception inspection.
4) Materials produced in-house might not have been confirmed finished in project stock.
5) Materials might have been changed to bulk materials that do not have stock balances.

Materials with error code 021 are consumed from normal stock. They are not allocated to a specified project. These materials are said to have unrestricted use.

### 4.4.3 Error code 018: Missing Storage Locations

The error code 018 indicates that no storage location for the material has been defined in this production order. Therefore SAP can not determine where to consume it from, or where finished in-house produced materials should be located. Consequently, no defined storage location causes the material to go on the error list. The materials on the error list that do not have storage locations can be materials that are consumed from several different locations. The reasons for this are explained below.

Production planners define the storage locations for purchasing and consumption in the material master data. If the goods are stored in an IM warehouse, they might have several different storage locations. However, in SAP material master data, only one purchasing and production storage location for a material can be maintained. This is because if ‘storage location for EP’ –parameter has a value defined in the material master data, the material will be purchased to the defined storage location as a default. Only one value for both of the locations – for purchasing and production - can be defined at a time. Sometimes the storage location field is intentionally left empty for the above-mentioned reasons.

With kanban-materials the situation is different. With them, several storage locations can be used. This is possible because kanban-materials are ordered to different supply areas and not storage locations. Each supply area then has its own storage location. This way it is possible to maintain several storage locations for a single material. It should be studied whether this way of working is also possible for other materials than kanban.

### 4.4.4 Other Error Codes

Error codes that occur more infrequently are 286 and 465. The message for error code 286 is “Deficit of Project st. unr. prev 1 PC: 0037C079300 FI06 100 Q”. The abbreviation prev. tells that the system is trying to make the posting for a period that is already closed, such as the previous month. This situation can occur if the material has been reported in project stock in the current period, but the error has occurred in the previous period. It is easy to manually clear these materials from the error list. The posting and document dates can be manually changed in transaction COGI for all the materials on the error list. Inserting a date from the current month to the posting date -field will clear these materials from the list.

The error code 465 message is “No price could be determined for material/batch PAAE015527/ plant FI06”. When no price has been defined for a material, it is impossible for the system to know how much costs it should register on the production order. Therefore an error will occur and the material will go on the COGI-list.

Materials that are purchased usually do not have this problem since their price is defined in the contract. The purchased materials have a moving price, whereas with in-house produced materials a standard price is used. The standard price is determined by a pricing run, which is performed by the finance department. In order to perform the pricing run, the material structure and routing need to be known. If the pricing run has not been performed when the in-house produced materials are consumed, they might go on the COGI-list. They will only be cleared from the list once the pricing run has been executed.

## 4.5 Production Schedulers

The production schedulers with which most errors occur are of interest because the data clarifies where the errors physically take place. The errors per production scheduler data is presented in the figure below:

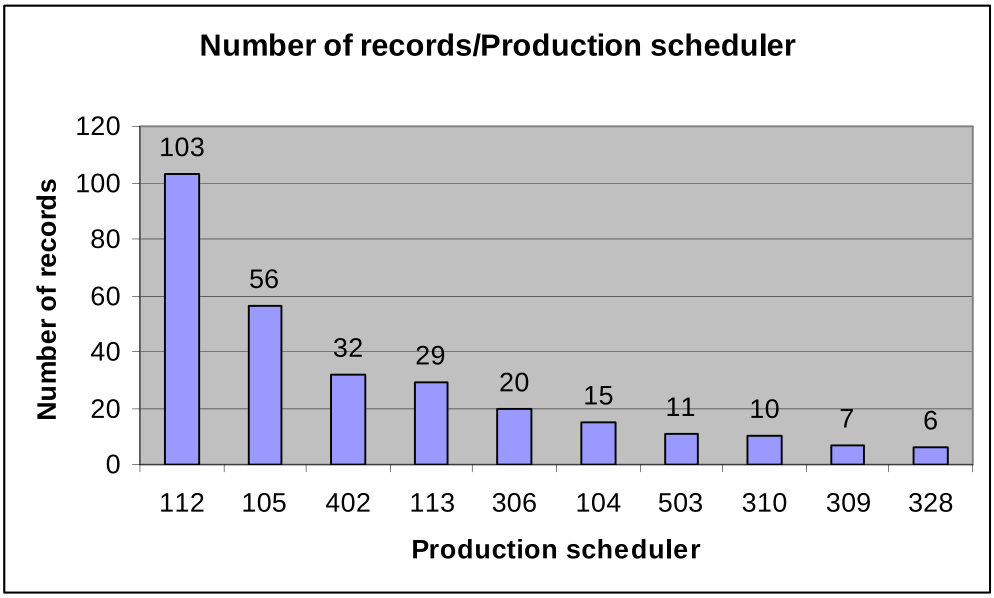


**Figure 11.Errors per production scheduler.**

The production scheduler codes in SAP are explained in the following table:

| | |
|---|---|
| 112 | Material receptions stocks and |
| 105 | Main assembly W32 |
| 402 | Tool Manufacturing, Vaasa, MF |
| 113 | Pipe center |
| 306 | Nut manufacturing |
| 104 | Engine block subassembly, W32 |
| 503 | Main assembly W20 |
| 310 | Bearing parts, Okuma 35 |
| 309 | Bearing parts, Okuma 25 |
| 328 | Ryntösäiliö |

**Table 6.Production scheduler codes in SAP.**

The production scheduler is a production controlling code and indicates who is responsible for the manufacturing and the scheduling. The picture does not state the reason why the materials appear on the error list, it simply illustrates the physical location in which the errors occur.

A production schedule is available to each of the schedulers. Each manufacturing machine can have its own scheduler, or the scheduler can be workshop-specific. This depends on which level the production is controlled.

The production scheduler could also be called a manufacturing cell. Several cells can belong to one scheduler area.

The production scheduler 112 is the set center. The most probable reason why the set center leads this statistics is that many of the materials with erroneous material movements belong to a set. The large amount of errors occurring in the set center is also partially explained by the fact that a large mass of materials is managed and handled there. The same applies to the production scheduler 105, the main assembly of the W32 factory.

## 4.6 Operation Confirmer and MRP Controller –Specific Error Statistics

It has also been studied who creates the most error records in the system. The statistics are presented in figure 12 below.

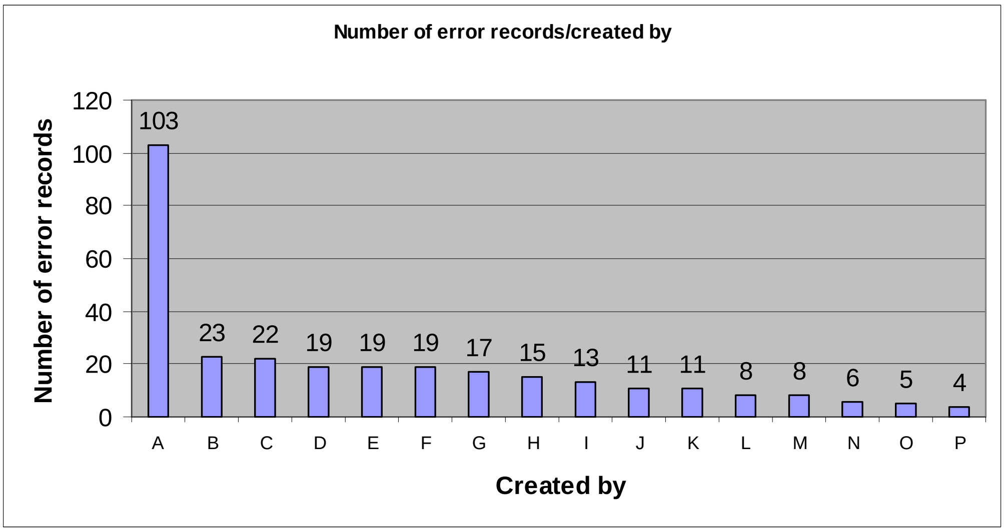


**Figure 12.Errors per operation confirmer.**

If the material contains errors, the materials go on the error list after the production order operation in which they are needed has been confirmed. This picture indicates who made the confirmation of the production order operation, which caused the material to go on the error list. Some of these are persons, some are user groups used by factory workers that do not have their own individual SAP username. The real usernames and groups are not presented in figure 12 for privacy reasons.

Statistics about the MRP controllers of the materials on the COGI-list have been created as well. Numbers of error records per MRP controller are presented in figure 13:

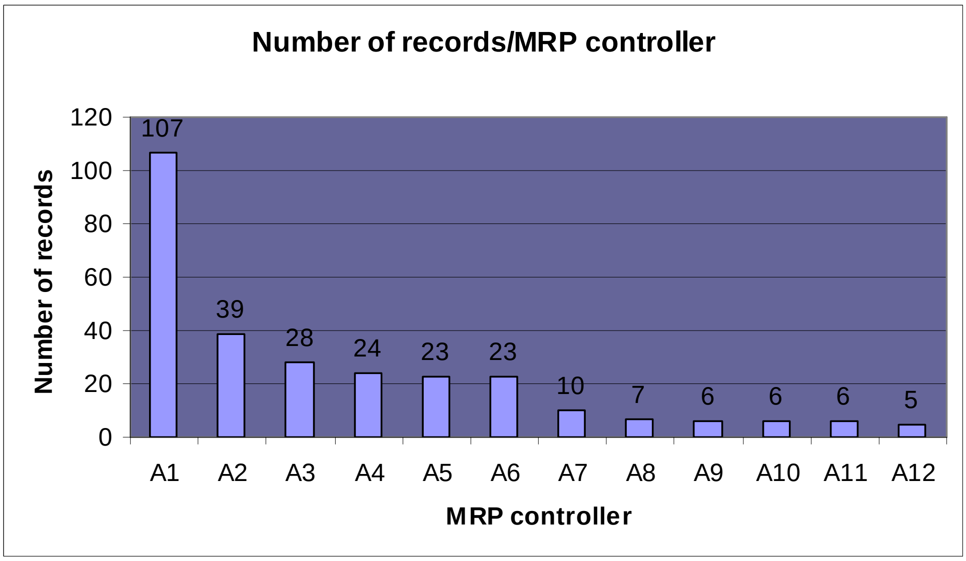


**Figure 13.Errors per MRP controller.**

The MRP controller expresses who is responsible for the materials. Some of the MRP controllers are persons; some are controller areas. The controller area can be called a workshop code; it consists of more than one person or machine. If the MRP controller is an individual person, the material has been purchased from a supplier outside Wärtsilä. In that case the MRP controller is the purchaser. If the MRP controller is a controller area with more than one person in it, the material has been manufactured in Wärtsilä. The materials that appear on the error list may be either purchased from outside suppliers or manufactured in-house.

The large portion of the controller A1 is explained by the fact that this MRP controller is responsible for the troublesome 0031C-materials. Since the 0031C-materials dominate the COGI -error list, their MRP controller naturally dominates figure 13. Once the problems with these materials have been solved, the MRP controller proportions of this statistics will become more even.

Again, figure 13 does not say anything about the reason the materials are on the error list, it simply states who is accountable for the materials appearing on it. Real MRP controller codes are not presented in figure 13 for privacy reasons.

## 4.7 Problematic Use of WBS-Controlled Materials

Some materials need to be classified by an external classification society. In order for a material to be classified, the classification society needs to know which project it is assigned for. This is one of the two reasons why WBS-controlled materials are used.

Unfortunately, during the implementation phase of SAP many materials have been needlessly defined to be WBS-controlled. They were defined WBS-controlled based on the fact that the use of WBS-controlled materials was common in the legacy system IManu. During SAP implementation the new system was not known well enough to predict that the excessive use of WBS-controlled materials will cause problems down the road.

Sometimes materials or parts that are assembled to an engine are “borrowed” from another project. This is done when a material assigned for the engine being assembled has not been delivered yet. Waiting for the arrival of this material would delay the production process. However the same or similar material assigned to a different project might already be delivered and available in stock. In that case the available material may be borrowed to the project that it was not originally allocated for.

Borrowing materials from other projects is not prohibited and it is sometimes necessary in order to avoid delays. The problem is that the system does not understand the borrowing. It has allocated a certain material to a certain project. If the materials were not assigned for a certain project and tagged with a WBS-element, this problem would not exist.

Other problems with WBS-controlled materials are related to the pre-ordered materials, especially home-calling and goods reception reporting. These issues are addressed more thoroughly in the chapters below.

## 4.8 Pre-orders and Home-calling

Figure 14 illustrates what are the shares of the two MRP profiles from the errors of the WBS-controlled materials:

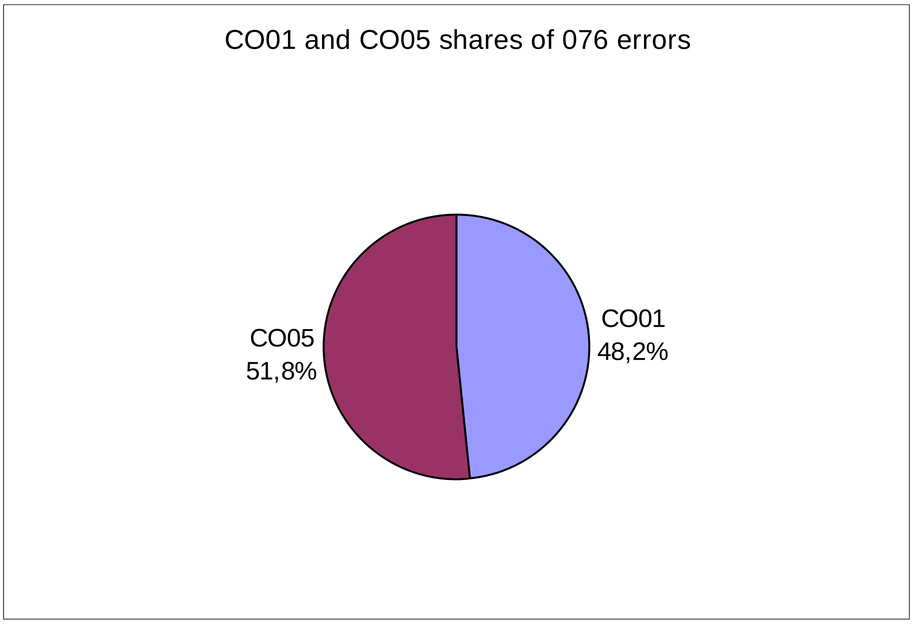


**Figure 14.MRP profiles of errors with code 076.**

Materials that have the error message 076 can have two different MRP profiles: CO01 and CO05. The MRP profile contains the necessary data for the material master – it defines the material's directing parameters. The MRP profile data is required for updating the material master record for material requirements planning.

CO05 materials are pre-ordered materials, and CO01 are normal project ordered materials. A pre-order is a special type of purchase order. The supplier will not deliver the pre-ordered materials before a home-calling has been performed. The home-calling should always be done for a specific date – the date when the pre-ordered materials are needed for production.

In relation to each other both normal project ordered and pre-ordered materials appear on the error list almost equal amount. In reality, the number of pre-ordered materials is much smaller than normal project ordered materials. Hence, the materials that need the home-calling seem to be causing a great deal more trouble than those that do not need it.

Home-calling is generally only used in W32. The home-calling is performed by a production controller who is responsible for the home-called materials. Also production supervisors do home-calling. At the moment these employees do not have the knowledge about the problems related to home-calling. They are not aware of the problematic consequences of the deficiencies in the home-calling process.

The use of pre-orders gives the supplier time to manufacture the required materials. That way the supplier can time the manufacturing so that the materials are ready to be delivered on the home-calling date. Another reason why pre-orders are used is very simple: the lack of space. Some of the pre-ordered parts are so large that they can not be received to the warehouse before they are really needed. This is usually the case with large sets. The solution is to deliver these materials directly to the production line.

### 4.8.1 Deficiencies in Home-calling

In most cases the error in the home-calling process is caused by the fact that the home-calling is done deficiently. The purchase order exists, but the home-calling date has not been registered in the system. This does not directly cause materials to go on the COGI-list. Problems arise when the neither the home-calling, nor the goods reception reporting has been done. In that situation it is not traceable from the system whether these goods have arrived at the factory site or not. The chapters below look at the reasons and consequences of the deficiencies in both home-calling and reception reporting.

The reasons for the lacking home-calling can be several. Sometimes during production it is decided that another material will be used instead of the material that is already pre-ordered. If this is the case, the home-calling will not be done at all since that pre-ordered material is not considered necessary anymore. If nothing is done, the material will remain on the error list and the system will show that such a material has been ordered but neither the home-calling nor the goods reception has been done.

With some vendors the home-calling is done on the phone, via fax, or with the generator assembly program. In the latter case the generator assembly program document is sent to the supplier, who then delivers the materials according to the program; on the days they are needed for production. When the home-calling is done some other way than in SAP, the home-calling date should be registered in the system separately. This is double the work for the home-caller.

When the home-calling takes place some other way than through SAP, the home-calling date is often not registered in the system. Also when the home-calling is done some other way, usually all the materials that belong to a certain project are home-called. In other words, the home-calling is done based on a WBS-element, whereas the system requires it to be done for each material individually. This consequentially leaves a group of materials in the system without the necessary home-calling dates.

All in all, the current situation with the materials requiring home-calling is disparate. According to a recent policy given in the purchasing department, the home-calling date should always be registered in SAP. In theory this should prevent the registration problems occurring from home-calling made on the phone, by fax, or with the generator assembly program document. Despite the policy, these other methods are still widely used to perform the home-calling.

### 4.8.2 Deficiencies in Goods Reception Reporting

The worst case scenario is when neither the home-calling nor the goods reception is registered in the system. In that kind of a situation the materials do not exist in stock at all from the system point of view. In that case they can not be consumed from stock either. When the system tries to consume these materials, they go on the erroneous material movements list. This situation has also another unwanted consequence: distortions in stock balances.

When the goods reception reporting is done deficiently or is not done at all, the stock balances in the system will become distorted. Distortion in a stock balance in turn causes the material to appear on the COGI-list more frequently when the system shows that it does not exist in stock at the time of demand and consumption.

The pre-ordered materials are not placed in the warehouse to wait for usage; instead they are required to be delivered directly to the production line. In practise this means that the goods are delivered to the goods reception located in the W32 factory, or at the door of the W32 factory. The policy is that at least the documents – the packing list and the waybill – are to be delivered to the goods reception. Often the documents only end up in the production site. The production site does not do the goods reception reporting in SAP; it is the responsibility of the goods reception personnel. However, it is impossible for the goods reception to do the reporting if they never receive the necessary documents.

The carrier – in practise the driver of the transporting vehicle – is responsible for taking the delivery documents to goods reception. If the driver has not delivered the papers, the forklift driver should do it. The packing list often has the number of the order printed on it. The goods receipt is usually done against the order number.

Each delivery is also required to have a waybill. According to the rules, a confirmation of the goods reception is required on the waybill before the carrier can leave the goods. Many of the Wärtsilä suppliers are from the neighbouring area, and the cooperation has been going on for years. With this kind of suppliers the way of working does not always follow the policies.

Sometimes there are delays in the goods reception reporting. This can result in a situation where the materials are already consumed before they have been reported received. This causes confusion in the stock balances: sometimes there is stock deficit in the system when in reality the materials are available to consumption. Sometimes the materials can appear on the COGI list as a result of this seeming stock deficit. Later when the reception reporting is done, they can be cleared from the error list without further measures. Therefore delays in goods reception reporting sometimes cause materials to temporarily appear on the error list.

As well as with the home-calling, no clearly defined way of working exists for the goods reception. Defining clear procedures for the unclear steps of the goods reception should reduce the numbers of errors made.

# 5 Analysis and Findings

## 5.1 Solving the Problem with 0031C-materials

The best possible solution for the fitted plates with material numbers 0031C would be changing the materials so that they would be purchased normally to the warehouse, and would not require home-calling. This requires a change in the materials' MRP profiles. In order to know that the MRP profile change is really required, it is necessary to observe the consumptions of these materials as they appear in the system. The following table illustrates the consumptions of the most problematic materials as they are registered in SAP:

| Material | Total usage | | Total usage value | |
|---|---|---|---|---|
| 0031C056406 | **682** | PC | 14 880,07 | EUR |
| 0031C056405 | **676** | PC | 14 747,56 | EUR |
| 0031C056402 | **532** | PC | 11 620,46 | EUR |
| 0031C056404 | **532** | PC | 11 620,46 | EUR |
| 0031C056403 | **380** | PC | 8 229,72 | EUR |
| 0031C056401 | **338** | PC | 7 373,78 | EUR |
| 0031C052204 | **244** | PC | 5 780,21 | EUR |
| 0031C057200 | **222** | PC | 6 396,31 | EUR |
| 0031C052205 | **204** | PC | 4 687,19 | EUR |
| 0031C052203 | **180** | PC | 4 260,45 | EUR |
| 0031C052201 | **180** | PC | 4 260,45 | EUR |
| 0031C030300 | **122** | PC | 2 903,50 | EUR |
| 0031C060700 | **120** | PC | 2 861,93 | EUR |
| 0031C056500 | **114** | PC | 2 706,30 | EUR |
| 0031C056407 | **84** | PC | 1 860,18 | EUR |
| 0031C052202 | **64** | PC | 1 546,54 | EUR |
| Total | 4674 | PC | 105 735,11 | EUR |

**Table 7.Consumptions of the fitted plates according to SAP.**

The data in this table is from a time period of one year: between May 2005 and April 2006. The materials that are on the COGI-list do not show in these statistics; this contains only the confirmed consumptions. The table shows that on a yearly basis quite a large amount of money is involved, although the average price for one piece is just above 20 euros. However, this is not mainly a money issue but a system issue. These materials cause problems in the system: a mass of materials in the COGI-list and confusions in stock balances. This table verifies that the consumptions of these materials are so significant that it would be best to purchase them to the warehouse.

Before the old MRP profiles can be replaced with new ones, permanent storage locations need to be defined for these materials. The material handling manager will define the new permanent storage locations together with the production supervisor who has been responsible for the home-calling of these materials until now.

Even when the MRP profile change has been completed, there is a mass of pre-orders of 0031C-materials in the system that have never had their home-calling dates registered. Some of them have also not been reported received. Therefore they have remained on the error list long after the engines for which they were needed have been finished. The required delivery dates of some of these materials are from the year 2005 but according to the system they have never arrived at the factory site. These pre-orders need to be closed as is discussed in chapter 5.2.3.

## 5.2 Other Material Related Changes and Issues

A number of other measures need to be considered for the rest of the mass of materials on the COGI-list; for example decreasing the number of WBS-controlled materials and pre-ordered materials in particular, and improvements in the goods reception reporting. These issues and possible measures are addressed in the chapters below.

### 5.2.1 Decreasing the Number of WBS-Controlled Materials

As is stated in chapter 4.7 a countless number of materials are WBS-controlled as if accidentally, because they were purchased and controlled with a WBS-element in the legacy system as well. There is no valid reason for some of these materials to be WBS-controlled in SAP. Chapter 4.7 also discusses the problems that the extensive use of WBS-controlled materials causes from the system point of view.

The situation could be simplified by changing the master data of some WBS-controlled materials, so that they would become normal stock materials. This requires changing the MRP profile data. This change would make the handling of these materials significantly more flexible from the system point of view. However, it might be difficult to reach a consensus about which materials could be changed. The way in which materials are purchased and controlled affects the work of the production planning, purchasing, and logistics departments. All three parties involved might not have similar views about which materials could be changed.

### 5.2.2 Materials Borrowed from Other Projects

Another problem related to the WBS-controlled materials is borrowing materials from other projects. The solution for the problematic consequences of the borrowing appears to be simple. A manual stock transport should be done in the SAP transaction MB1B every time a material is borrowed from another project. The first problem is that the stock transport needs to be done twice: once for the borrowed material and once for the original material that will not be used after all.

The main problem is that it is not clearly defined who is responsible for the stock transport. Because the responsibility question is currently open, the manual stock transport is not always done when necessary. The production that borrows materials from other projects is not responsible for the stock balances as such. The logistics department is in charge of the stock balances; from this point of view it would be the most natural choice to be responsible for the stock transport.

On the other hand, when a material has been borrowed the original material is not required for that project any longer. It is the purchaser who can change the purchase order for that material so that it is ordered for another project instead of the original project. If this is done only one stock transport is required. From this standpoint it would be most beneficial if the purchasing department was in charge of manual stock transports.

### 5.2.3 Decreasing the Number of Pre-orders

Some materials are pre-ordered even though they are used for almost every engine manufactured. Sometimes several of these materials are assembled into one engine. It could be useful to investigate how many of the pre-ordered materials truly need to be pre-ordered. One possible corrective action is to change a part of these materials into normal project-ordered materials. This would require their MRP profile to be changed from CO05 into CO01. The result would be a reduction in the number of home-called materials and thus an inevitable reduction in the number of related problems.

The problem with changing the pre-ordered materials into normal project ordered is the same as with changing the WBS-controlled materials into normal warehouse ordered: there are three different parties who are interested in the way the materials are controlled. These are the production planning, purchasing, and logistics departments. The production planning establishes materials and does the coding of the material data in the material master. The logistics department is interested in controlling the material flows in the warehouses and production site. The MRP profile also significantly influences how the materials are purchased. It can be difficult to reach a consensus between all the parties about the material master data changes.

There is also another significant factor to consider: the lack of space. It is possible that there simply is not enough space that these materials could be taken into stock as some of them are delivered in large sets. On the other hand, some of the materials are very small in size. It should be feasible to arrange some space in the warehouse for the smaller pre-ordered materials.

Even after the possible changes are done, the mass of open pre-orders that have never been home-called exists in the system. These orders need to be closed for the system to know that they are not going to be needed. The purchaser needs to cancel the pre-order; the orders can not just be deleted.

The other option is to perform the home-calling for all of these materials, do the goods reception reporting, and then determine what to do with the received materials. This is the easiest and simplest solution. If the materials are not needed for production they can be scrapped and disposed. However, Wärtsilä has committed to buying these materials when the orders have been placed.

### 5.2.4 Pre-ordered Mass Materials

As was stated in chapter 4.8.1 some materials are home-called based on the WBS-element, or using the generator assembly program. The home-calling dates of these materials are not registered individually in the system as they should be. From the system point of view this is an erroneous way to perform the home-calling and causes all of these materials to go on the COGI-list.

One reason these materials are not home-called individually is the large mass of them. This means that with some pre-ordered materials 75 to 100 pieces of one material is used during the time period of one month. Approximately 15 to 20 pieces of these materials are needed for the assembly of each engine. The troublesome materials with material numbers 0031C belong to this group. It is not efficient or reasonable to expect these materials to be home-called one by one; the production supervisor responsible for their home-calling would not have time to do anything else.

With these mass materials, the possibility of ordering them as a group should be considered. This means that all the materials needed for one assembly stage would be ordered as one lot under the same order number. That way they could possibly still be pre-ordered if that proves to be necessary. If this is not feasible, they could be purchased to the warehouse. In either case, they would not need to be home-called individually any longer.

### 5.2.5 Goods Reception Improvements

It seems that most of the problems with goods reception reporting arise from unanswered responsibility questions. It is justified to expect that if these responsibilities were clarified, the errors would decrease.

Most importantly, it should be firmly defined whose responsibility it is to ensure that the necessary documents are delivered to the goods reception even when the goods are delivered straight to the production site. It is easier to give orders in-house, therefore the policy should be that the forklift driver is ultimately responsible for delivering the papers to goods reception. No exceptions should be accepted. The minimum requirement should be that the packing list is delivered to the goods reception. This is vital since the packing list has the order number against which the goods reception reporting is usually done.

It is essential that the goods reception is documented, this information might be required later on. It is important to know when certain goods arrived and in what quantities. The quality of the goods might be of importance as well. Therefore it should also be obligatory that a confirmation about the goods reception is marked on the waybill before the carrier leaves the goods. The carrier should follow this principle without exceptions as well.

## 5.3 Human Resource Solution Alternatives

Even if the so called technical changes were implemented successfully, it seems that additional employee resources are needed. The problems of the COGI-list can not be entirely eliminated or the list efficiently maintained without employing at least one additional person. The following chapters discuss the two best alternatives: a specific material movement production controller for W32 main assembly, and a general COGI-responsible in the logistics department. Hiring either or both of those can be considered.

### 5.3.1 Production Controller for W32 Main Assembly

As is stated in chapter 4.2 most material movement errors of the COGI-list occur in storage location 100; the large warehouse of the W32-factory. The production supervisors do most of the production order operation confirmations and home-callings in the W32-factory. As the situation is now, the supervisors do not have the time or the know-how to solve the problems that sometimes follow the operation confirmations and insufficient home-callings.

One possible solution could be hiring a production controller particularly for the material movements’ point of view. The production controller’s responsibilities could be the monitoring and the follow-up of material movements. It would the controller’s task to ensure that the problems caused by the confirmations are solved and cleared from the system. The production controller could also be the right person to make the production order operation confirmations. This would ensure that the confirmations are done correctly and do not cause extensive problems.

### 5.3.2 COGI-responsible

Even if all the other corrections discussed in chapter 5 were successfully executed, the list of material movements with errors would still most likely require constant observation. The obvious goal is that the list would require as little attention as possible. Still, someone needs to keep track of how many rows the erroneous material movement list contains at any point of time. If the list is not continuously controlled by doing the manual clearings, the mass of materials will keep cumulating.

Taken this into consideration, it might be necessary for the logistics department to employ an extra resource to deal with the COGI-related issues. However, dealing with the COGI-issues is not a full-time job; it could be one part of this person's sphere of responsibilities. The tasks would be the manual clearing of errors, solving the real statuses of unclear orders in cooperation with purchasers, finding out missing storage location data, and so on.

Employing a COGI-responsible is not a solution to the problems as such. It can be seen as a remedy with which the disease is being medicated, whereas the above mentioned measures would concentrate on curing the disease itself. However, it might be that hiring a COGI-responsible is the most viable option. This person would be able to put effort into solving the erroneous material movement problems. He or she would become an expert who would be able to consider all the factors involved in the COGI-issues. The COGI-expert would be able to see the whole picture, which is not possible for employees who mainly concentrate on their on field in the production process. This would enable the COGI-expert to effectively solve the erroneous material movement problems.

## 5.4 System Changes

Theoretically, the confirmation process in the system could be changed quite radically. The confirmation process could be changed so that if the operation contains errors, it can not be confirmed finished before the errors have been corrected. This would effectively stop the errors from piling up in the erroneous material movements list. On the other hand, this kind of a system change does not allow any kind of false material master data or distortions in stock balances; both would have to be absolutely accurate.

The problem with this radical system change is that is errors in material movements would cause the production process to stagnate. If operations can not be confirmed completed, the whole project can not be confirmed finished either. Consequently it would impossible to deliver the engine to the customer or do the invoicing. Hence, this change would eliminate the flexibility required in the manufacturing process. Therefore it is only noted as a theoretical option.

## 5.5 Employee Training

In some cases simply training the employees might at least partly eliminate COGI-related problems. One measure that is likely to improve the situation with the mass of pre-ordered materials on the COGI-list is training the employees that perform the home-calling. It could be sufficient to briefly inform these employees about why it is so important that the home-calling is done for each material individually, and that the home-calling date is registered in SAP. On the other hand, this will not eliminate the problem with home-calling the mass materials for example.

Other fields where training the employees might have positive consequences are borrowing materials from other projects and changing materials during the assembly phase. It is necessary to inform the production controllers and supervisors about the difficulties that result from changing parts or materials of a project during the assembly phase, and how these difficulties can be avoided. The minimum requirement should be informing the party responsible for the stock transport if materials have been borrowed from another project. This way it is possible to avoid or at least minimize further problems resulting from borrowing materials.

# 6 Conclusions

Materials handling can greatly affect the company's overall costs. Handling material constitutes a substantial share of the manufacturing, distributing, and marketing costs. Therefore minimizing all unnecessary movement of material is one of the main material handling objectives.

Materials handling is also extremely crucial to effective warehouse operation. Other things that greatly affect the warehouse operation are the systems and techniques used in the company. The systems and techniques addressed in this thesis were SAP R/3, Just-in-Time philosophy, and Material Requirements Planning. These affects of these are visible in Wärtsilä Delivery Centre Vaasa.

The main object of this research was to clarify the reasons and sources for incorrect goods movements. The idea was also to make development suggestions and measures that aim at decreasing the number of incorrect material movement related problems. These targets were reached.

One major field of improvement is the convenience of the MRP profile data of certain materials in the materials master data. It was discovered that the extensive use of WBS-controlled materials creates various problems in SAP. This is especially true with the pre-ordered materials that require the home-calling before they can are delivered to the factory site.

Many of the WBS-controlled materials are that without any valid reason. Therefore it is vitally important to further examine which materials are truly necessary to be WBS-controlled and which are not. Changing the MRP profiles of the latter would eliminate a great portion of the problems related to the use of WBS-controlled materials.

The first option to be considered with the pre-ordered materials is to change the MRP profiles of as many materials as possible so that they would be normal project-ordered. Otherwise the home-calling process of these materials needs to be made more effective. It needs to be made sure that the home-calling dates are always registered in SAP. No exceptions can be allowed.

Other fields where rationalization is necessary are the goods reception reporting and borrowing materials from other projects. With these, defining clear rules and policies as to how the procedures take place is sufficient.

Although the development suggestions presented in this thesis would greatly improve the situation with the incorrect goods movements, some limitations exist. When planning to change the coding of materials in the material master data, it is difficult to determine which of the WBS-controlled or pre-ordered materials could possibly be changed. Production planning, logistics, production and purchasing departments would have to reach a consensus on the issue.

Another significant limitation when trying to eliminate the problems with the incorrect goods movements list is the lack of time and human resources. Therefore this thesis suggests that more resources are hired. A specific COGI-responsible needs to be appointed. Also an additional work supervisor in the W32 production is necessary. Either or both of these should and will be hired.

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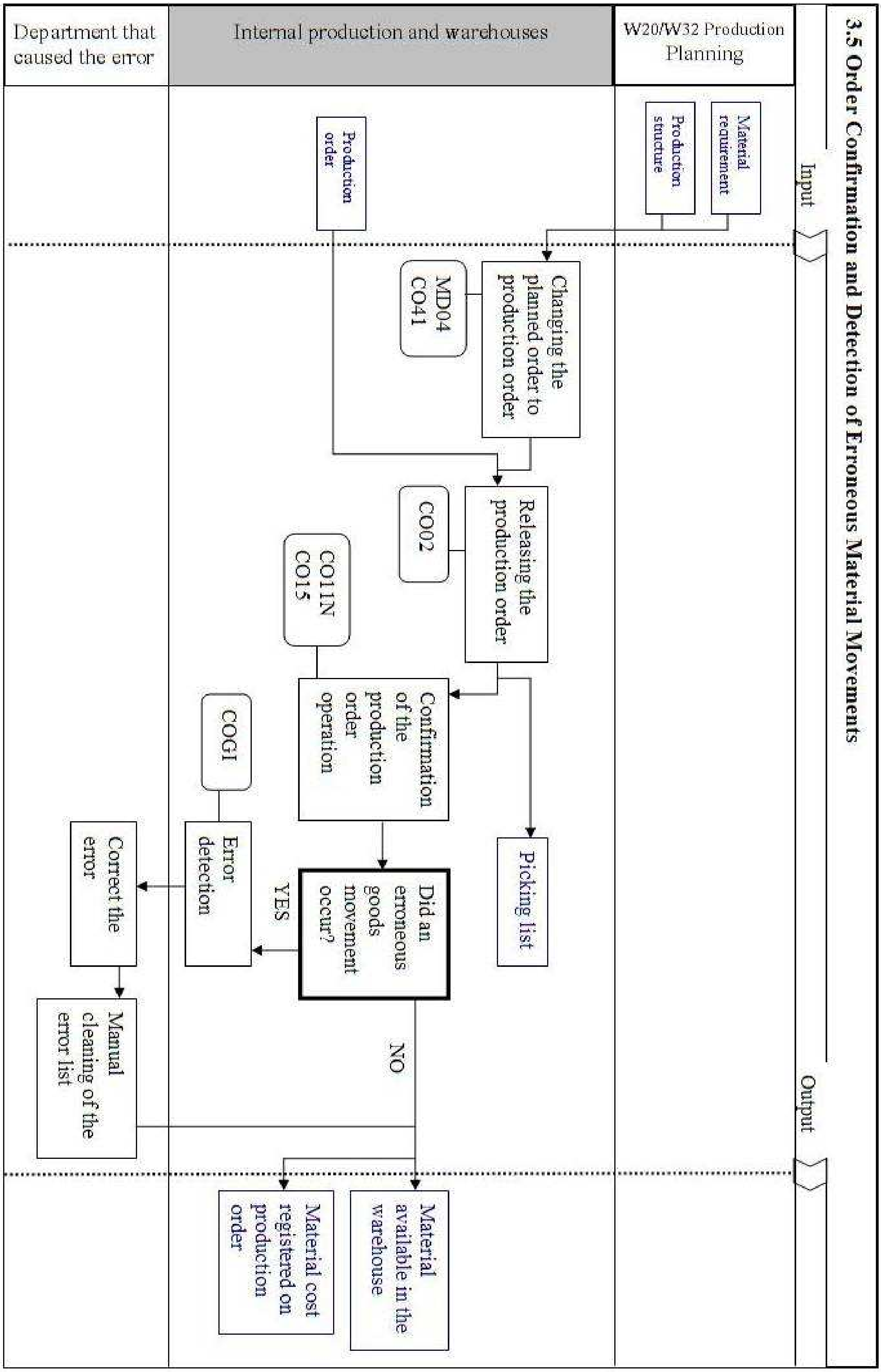
3.5 Order Confirmation and Detection of Erroneous Material Movements
Input
Output
W20/W32 Production Planning
Internal production and warehouses
Department that caused the error
Material requirement
Production structure
Production order
Changing the planned order to production order
MD04
CO41
Releasing the production order
CO02
Picking list
Confirmation of the production order operation
CO11N
CO15
Did an erroneous goods movement occur?
YES
NO
Error detection
COGI
Correct the error
Manual cleaning of the error list
Material available in the warehouse
Material cost registered on production order