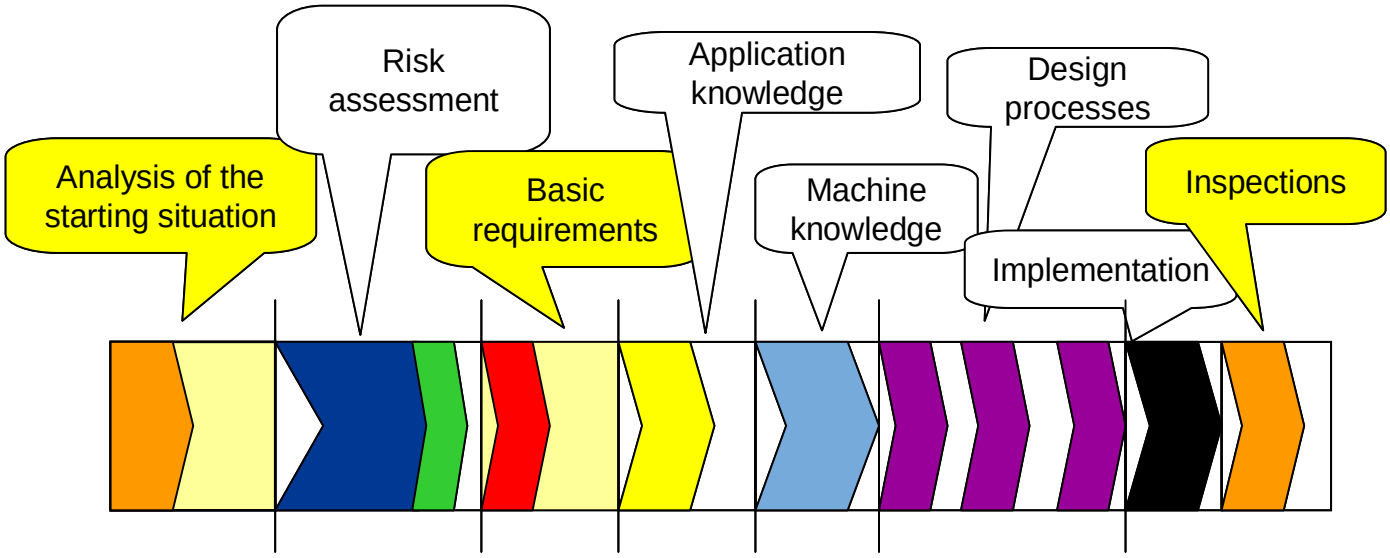
RESEARCH REPORT

VTT-R-05719-10



Safety-conscious modernisation of machines and production lines

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Confidentiality: Public

Report's title	
Safety-conscious modernisation of machines and production lines	
Customer, contact person, address Work Environment Fund and project consortium	Order reference Project number 108308
Project name Modernisation of Automation in Machinery	Project number/Short name 30520/Autuus
Author(s) Timo Malm, Outi Venho-Ahonen, Vesa Hämäläinen	Pages 47/
Keywords Modernisation, safety, machinery, machine	Report identification code VTT-R-05719-10

Summary

Instead of ordering new machines, companies are nowadays more and more often modernising old machines, for example, to improve productivity, safety, maintenance, or compatibility with new products. This report highlights the array of safety issues that arise when used machinery, or a combination of machinery, is modernised.

Older machines should be handled according to Work Equipment Directive (89/655/EEC) and its amendments (95/63/EC, 2001/45/EC). In order to achieve a suitable solution, practices which aim to guarantee good communication, modernisation realisation, designation of responsibilities and timetable, are recommended.

This report introduces a model for a modernisation process. It presents all phases of the modernisation process for machinery in use and describes who is normally responsible for each task. The most common risks related to modernisation of machinery were sought by interviewing designers. The created list provides some insight into common ways of minimising the risks and from where one can find information. An example of a document "Safety description of a modernisation implementation" is also presented. The document offers information about what has typically been done during a modernisation process and which requirements have been applied.

Confidentiality	Public

Tampere 6.7.2010

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Distribution
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Preface

This guide, intended for safety-conscious modernisation of machines and machine lines, has been realised with the support of the Finnish Work Environment Fund. The text is based on work performed in the "Safety-concious Modernisation of Machinery" project, and the original version of this report was in Finnish. The report was originally translated by Metso Paper. As a part of the new project "Modernisation of Automation in Machinery", the report has been updated and some features related to automation have been added. The following persons have been participating in the current report development: Timo Malm, Outi Venho-Ahonen, Marita Hietikko, Jari Schabel, Helena Kortelainen (VTT), Reijo Laine, Jukka Alatalo, Eero Suomi (Metso Paper), Mika Kontio (Siemens), Pekka Röpelinen (Ruukki), Kenneth Johansson (Work Environment Fund) and Matti Sundquist (Sundcon Oy). Many other persons, mostly designers, project managers and the old project members have also taken part in this project, mainly through the numerous interview situations. Reijo Laine has had an important role in the compilation of the Appendices C and D. We thank all participants for their valuable contributions to the implementation of this guide.

Tampere, 27.8.2010

Authors

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1 Introduction

Instead of new investments, the option to modernise machines and systems is more and more often chosen in Finland. This trend has been already ongoing for years, even if it has been affected by economic fluctuations. The investment level in Finland has been 3.4 – 4.0 billion EUR. [6]

Almost as important as the modernisation, however, is maintenance, which is a more extensive activity. The annual volume of maintenance in Finland has been about 3.5 billion EUR. Maintenance typically includes: preventive maintenance, improving maintenance, clearing of fault situations and development of maintenance reliability. [7]

Modernisation of old machines enhances efficiency, and above all, the productivity can be considerably increased with new automatic functions. The main reasons for modernisation are here divided into four groups: mandatory or limiting factors, intangible factors, factors related to production (not direct cost factors) and cost/benefit factors.

Mandatory or limiting factors

- Availability of spare parts; running out of spare parts, spare part compatibility with other systems.
- Mitigation of the risk of severe accidents; severe accidents in the same industry sector, near misses, "safety letters" or risk due to machines/systems next to each other with different degrees of automation.
- Elimination of identified significant risk; new significant risk is identified – possibly related to economy, equipment, environment, people or other factors.
- Know-how of the system/ machine; masters of old systems are becoming rare, which makes production and maintainability more difficult. By using new technology it is easier to find trained personnel. People don't want to learn about obsolete technology.
- Properties of old vs. new systems; increased efficiency, running speed, accuracy, compatibility, etc.
- Old system/machine breaks down
- Environmental requirement fulfilment
- Occupational safety requirement fulfilment

Intangible factors

- Usability improvement (usability definition according to EN 12100-1)
- Ergonomic improvements
- Systems similarity; systems with varying ages could present problems for maintainability (spare parts management, personnel skills) and safety (different procedures and methods because of varying degree of automation).

- Enabling product variations; new products or changing quantity of model variations
- Changes required by a new product; the new features of the product may require a new system
- Product quality improvements
- System modifiability
- Compatibility with other systems
- Process real-time data improvements; requirements for real-time information of the process
- Diagnostic improvement; speeding up fault location
- Utilisation of new technology / new methods
- Imago improvements; safety, environment, energy, degree of automation, being pioneer, etc.

Factors related to production (not direct cost factors)

- Maintainability improvement
- Reduced need of system-specific trained personnel
- Increased degree of automation
- Rapid response & flexibility of the production
- Increased capacity
- Availability – system accessible; system may be out of operation for a variety of reasons, e.g. breakdown, malfunction, no skilled personnel, no material
- Reliability improvement – confidence in the system
- Decreasing amount of disturbances (excl. component failure)
- Reduced energy consumption (associated to smaller cables, devices, possibility to use batteries etc.)
- Reduced raw material consumption
- Elimination of detected problem; inoperability or problems of current system.

Several **cost factors** are involved, the most common of which are:

- acquisition price
- maintenance costs; more effective diagnostics will result in faster fault location
- energy consumption
- raw material consumption
- production speeding up (separate machine)
- capacity increasing (system expansion)
- availability; the system is in operation more often
- reliability improvement
- decrease in transient & intermittent failure frequency
- reduced significance of failures/malfunctions; failure significance is related to, e.g. failure extent and possibility to expand to the larger system, automatic failure recovery of the system, possibility of failure causing damages and production downtimes.
- decreasing the amount of second-rate products caused by failures/malfunctions
- increasing degree of automation

- productivity improvement – less personnel needed
- detected problems; inoperability or problems of current system.

Typically, the purpose of modernisation is to influence several of the factors mentioned above. For example, if there is a need to improve the safety, attempts will generally also be made to increase the productivity.

In machine tools, for example, normally when the control system is modernised, it may be useful to include other automation options. Automation, eventual auxiliary devices and increase of production capacity may change considerably the function and properties of a machine. Then, a new risk assessment must be completed, which may lead to new safeguarding solutions. When making modifications, safety will be estimated based on the Work Equipment Directive. The safety level of the machine may not be decreased due to the modification, but the purpose is to improve the safety.

Modernisation objects can be very old machines, and they are not as safe as new machines and machines constructed according to the Machinery Directive. However in some cases workers have learned to use an old machine in a safe way and changes to the procedure may actually decrease the level of safety. Utilisation possibilities of new safety engineering (e.g. photoelectric safety devices) should be considered in the modernisation process.

It may be difficult to determine the requirements related to the modernisation, if the contracting parties have a different idea about requirements and responsibilities. Even if requirements of the valid standards are not applied as such to the existing machines, they show the safety level that can be achieved today. In any case, the requirements of the Work Equipment Directive must be followed.

General requirements related to machines are discussed in Section 2 of this publication. The other sections focus particularly on modernisation, and the challenges posed by new investments are not discussed in this paper.

2 Requirements related to modernisation of machines

In Finland, the Machinery Act 1016/2004 provides the general framework for ensuring the safety of new machinery. And more detailed regulations are described in the Machinery Directive. The Machinery Directive entered into force in Finland at the beginning of 1995. Since then, the machines taken into use have had to correspond to the Machinery Directive and the essential safety and health requirements of its Annex 1 (if they are included in the application area of the Machinery Directive). The EC Machinery Directive 98/37/EC was replaced on 29 December 2009 by the new Machinery Directive 2006/42/EC. The old Directive may not be used anymore. In Finland the corresponding legislation is Machinery Decree VNa 400/2008. The Directive gives regulations mainly for machinery producers, how to make safe machines. Other regulations also can apply to a machine included in the application area of the Machinery Directive, for example the requirements of the decisions made by the Ministry of Trade and Industry according to the EMC Directive and Low Voltage Directive.

Occupational Safety and Health Act 738/2002 gives the general regulations for users. More detailed regulations are in European Work Equipment Directive (89/655/EEC) and its amendments (95/63/EC, 2001/45/EC). The corresponding regulation in Finland is called Work Equipment Decree VNa 403/2008 and it came into force 1.1.2009.

Figure 1 shows the relation between Machinery Directive and Work Equipment Directive. Machinery Directive is for machine builders and it is valid up to the moment the machine is in use. Work Equipment Directive is for machine users and it is valid the whole time the machine is in use. In Machinery Directive there are requirements for machine builders to design the whole lifecycle of the machine. This includes for example disposal.

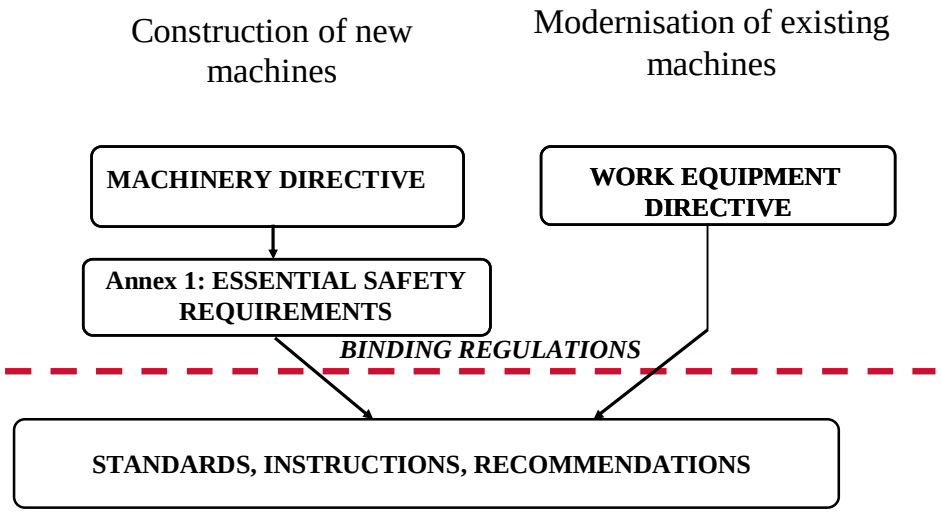

Figure 1. Machine safety regulations.

When identifying the modernisation requirements in an old machine, first, it must be decided, if a completely new machine will be acquired or if the old machine will be modernised. When acquiring or constructing a new machine, parts of the old machine may still be used if the requirements of the Machinery Directive can be met. Figure 2 presents questions related to this choice. Correspondingly, when there is a need to make changes in a machine line, either an entirely new machine line could be chosen, or modernisation of the old line can be undertaken.

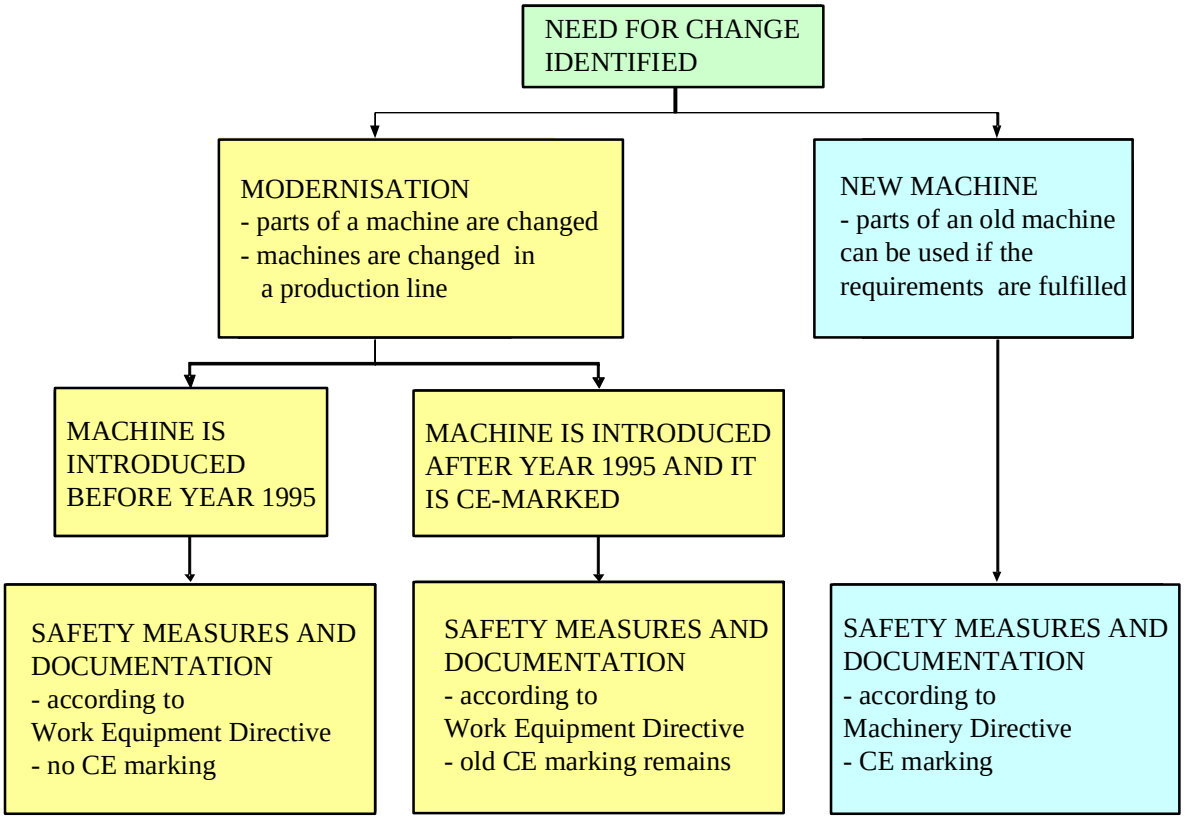

Figure 2. Choices to be made after identification of the need of changes in the machine: acquisition of a new machine or modernisation of the old machine.

Safety requirements are continuously developing so that they follow the current level of technology. At intervals of a few years, new safety technical solutions enter the market, and when they become common, they become new requirements for machines. Often, these safety solutions are applicable to the old existing machines also. Figure 3 presents the development of the safety level in comparison with the different requirements. It is difficult to compare the requirements of the Machinery Directive and Work Equipment Directive, because the Machinery Directive together with harmonised standards is more detailed and the Work Equipment Directive gives more choices for consideration and the conditions at workplace are taken into account. Harmonised standards describe the current level of technology, and they interpret the Machinery Directive. Old machines, also the ones taken into use before 1995, need to correspond to the Work Equipment Directive. This means that the older regulations are no longer valid (since 1998).

Regulations of the Work Equipment Decree VNa 403/2008 (Work Equipment Directive) are directed to the employer at workplace, and the requirements are applied to individual machines and other work equipment by taking into account the conditions at workplace. Work Equipment Directive concerns not only the machines, but also all other equipment to be used for work.

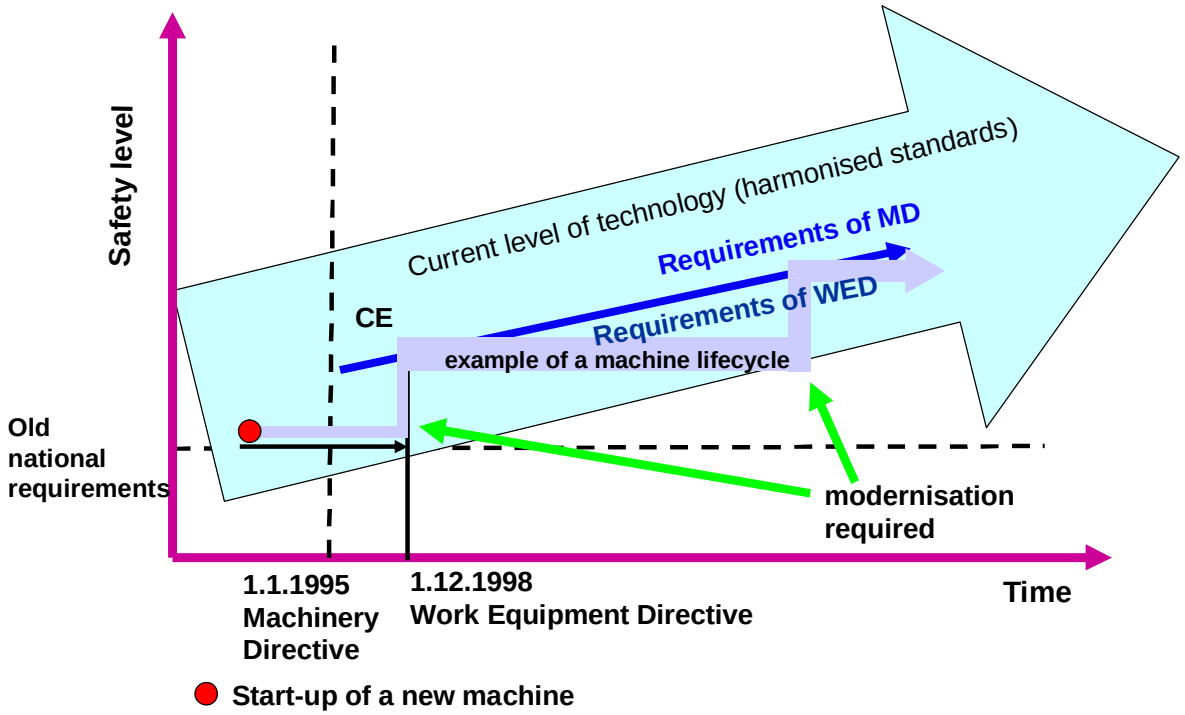

Figure 3. Development of machine safety.

Employer general responsibility to take care of work equipment propriety has been emphasised in Work Equipment Directive. The Work Equipment Directive includes, for example, the following general obligations:

- The employer must undertake necessary actions to ensure that the work equipment given to the employee to be used is suitable and safe for the work in question and for the working conditions, and that the work equipment is located so that the employee can use it without endangering their safety or health. Also ergonomics has to be taken into account.
- Employer has to ensure that manufacturers instructions are followed when assembling, using, maintaining, inspecting, etc. the work equipment. In addition employer has to ensure that worker can follow the instructions and employer has to update the instructions when needed. Instructions have to be available and understandable for the workers the instructions are related to.
- Employer has to clarify and assess the safety of work equipment in systematic way especially when having production or process modifications. Employer immediately has to start mitigating actions if the use of working equipment causes any hazard or harm.
- The work equipment has to maintain safe during whole operating life by regular maintenance and repair. Correct assembly and safe working condition of the work equipment has to be ensured especially before commissioning and after any alteration which effects on safety. Employer has to continuously follow up the condition of the work equipment by inspects, tests, measurements, etc.
- The guards and protection devices must reliably and appropriately insure against those dangers which why they has been installed. The guards and protection devices must be of robust construction, not give rise to any additional hazard, not

be easily removed or rendered inoperative, be situated at sufficient distance from the danger zone, not restrict more than necessary the view of the operating cycle of the equipment and allow operations described in Work Equipment Decree 12§ concerning safety of the maintenance work.

- The work equipment must be equipped with warning devices and warning signs and markings to ensure the safety of the workers. Signs and markings must be unambiguous, easily observable and understandable.
- Except where necessary for certain control devices, control devices must be located outside danger zones and in such a way that their operation cannot cause additional hazard. They must be covered to be sure that no unintentional operation is possible. Control systems must be safe. When possible, they have to be secured not to cause any hazard if having a failure or energy state alteration in control systems.
- It must be possible to start work equipment only by deliberate action on a control provided for the purpose. (This requirement does not apply to restarting or a change in operating conditions as a result of the normal operating cycle of an automatic device.). Before starting the work equipment, from the main control position, the operator must be able to ensure that no person is present in the danger zones. If this is impossible, a safe system such as an audible and/or visible warning signal must be given automatically whenever the machinery is about to start. Then the worker must have the time to exit the danger zone or the means to avoid hazards caused by the starting and/or stopping of the work equipment.
- Work equipment must be fitted with a control to stop it completely and safely. Each work station must be fitted with a control to stop some or all of the work equipment, so that the equipment is in a safe state. The equipment's stop control must have priority over the start controls. When the work equipment or the dangerous parts of it have stopped, the energy supply of the actuators concerned must be switched off. Where appropriate, and depending on the hazards the equipment presents and its normal stopping time, work equipment must be fitted with an emergency stop device.
- All work equipment must be fitted with clearly identifiable and when necessary lockable means to isolate it from all its energy sources.
- Employer has to ensure several points described in the "Work Equipment Directive" concerning work equipment assembly, maintenance, repair work or other technical servicing.
- Employer has to ensure that weather conditions do not risk the safety or health of the employee.
- Special competence requirements. Some competence requirements are stated for the crane and fork-lift driver
- The "Work Equipment Directive" also states some especial competence requirements for the crane and fork-lift driver and it has additional requirements for: moving work equipment, hoisting devices, high-structure erection work, and commissioning inspections, periodic inspections and condition monitoring system.

Requirements of the Work Equipment Directive [2] have partly the same contents as the safety and health requirements applied to new machines in the Machinery Directive. The

Work Equipment Directive includes less requirements, however, and some of them are of general nature.

On grounds of the Work Equipment Directive, a higher safety level than what is presented to new machines in the Machinery Directive can not be required of existing machines, unless the specific conditions at workplace, on grounds of a risk assessment, otherwise indicate. For example, use of a device in an explosion hazardous area requires that the requirement of the ATEX Directive is taken into account as an additional requirement due to the device class and place of use.

Application of the requirements of the Work Equipment Directive is based on risk assessment, and therefore, the conditions at workplace and all other relevant factors must be taken into account in the risk assessment. Standard ISO EN 14121 and the methods presented in it can be used to support the evaluation.

When modernising a system, the responsibility questions often come out, because there are more choices to consider than when constructing new machines (the conditions at workplace for example). When modernising a system, the responsible parties are generally the purchaser and the party implementing the modernisation, equipment suppliers and subcontractors. Even if the implementing party of the modernisation would not be the original manufacturer of the machine, it is often necessary to have a contact with the original manufacturer in order to get information about the structural properties of the machine and to be able to estimate the influences of the modifications. This concerns for example the modifications to be made in the strength properties, control systems, software and electric and hydraulic systems of the machines. Each party is responsible for the safety of the final result for its own part: suppliers of components, subsystems and devices, suppliers of safety systems, designer and implementing party of the modernisation, and finally, the purchaser (user). Figure 4 and Figure 5 present responsibilities of different parties of a modernised machine.

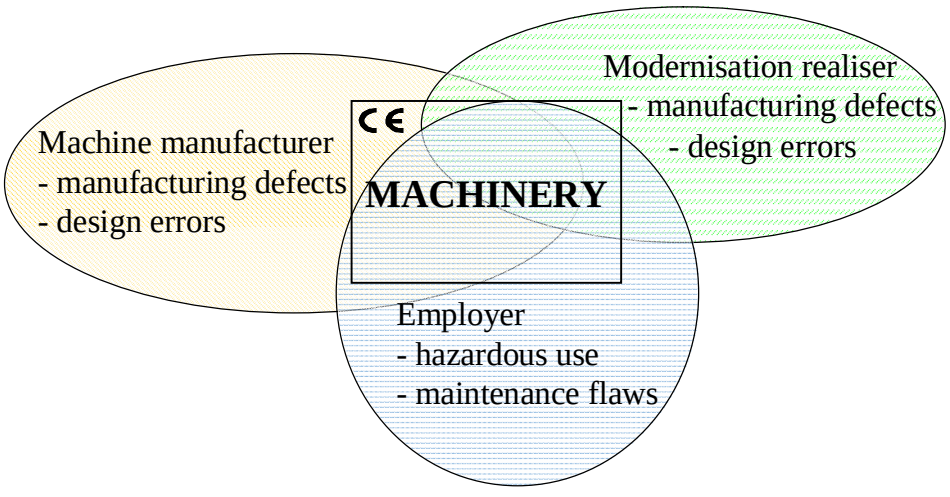

Figure 4. Simplified presentation of responsibilities of a modernised machine.

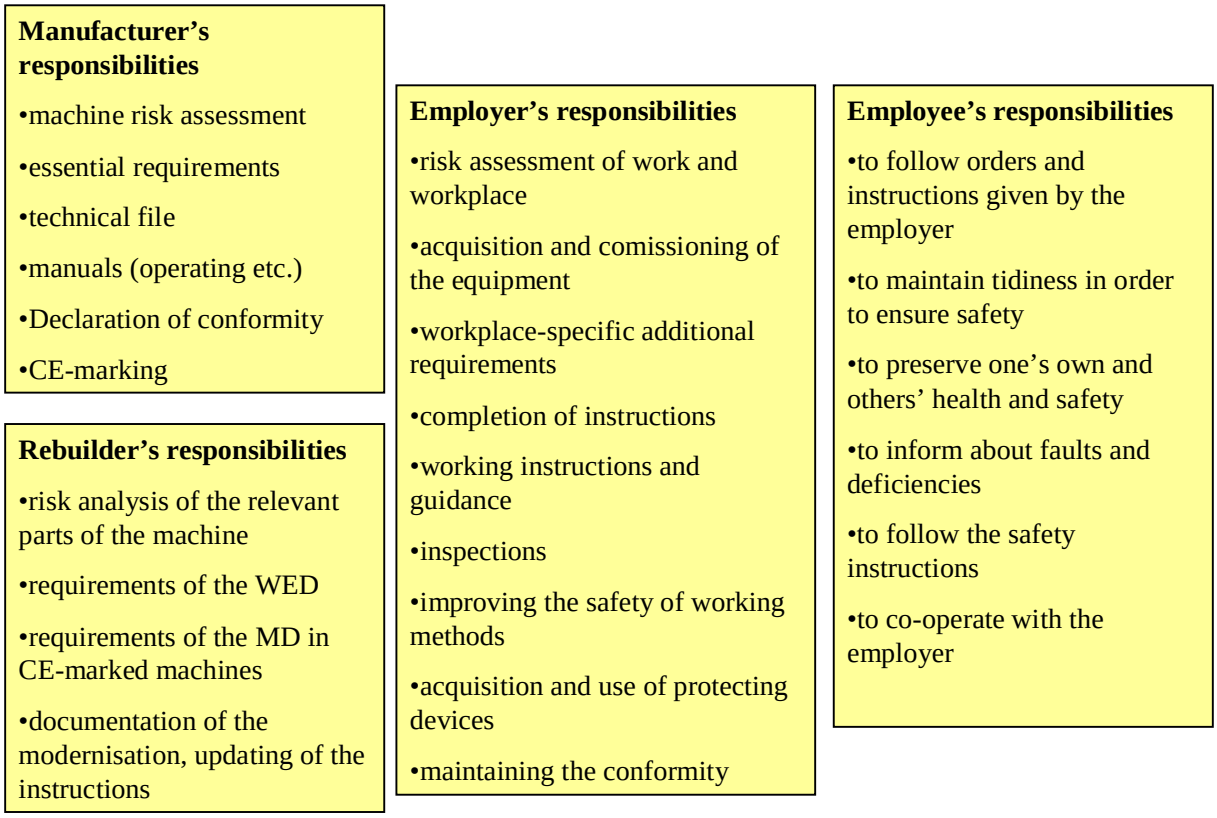

Figure 5. Responsibilities regarding a machine at workplace. Responsibilities of the manufacturer and rebuilder are connected to the moment of delivery, whereas the responsibilities of the employer and employee are connected to continuous activity. [3]

Figure 5 presents mainly aspects related to the Work Equipment Directive and the Machinery Directive, but there are also regulations given on the basis of other directives, such as:

- ATEX Workplace Directive concerns the potentially explosive atmospheres, and ATEX Equipment Directive concerns the equipment used in potentially explosive atmospheres.
- Low Voltage Directive concerns the electric shock hazards in alternating voltage range 50 - 1000 V and direct voltage range 75 - 1500 V.
- Vibration Exposure Directive concerns the vibration exposure of persons.
- Noise Directive concerns for example the noise exposure of persons.
- EMC Directive concerns the electromagnetic emissions of electrical equipment, and on the other hand, also tolerance to electromagnetic radiation.

Some devices and machine groups are subject to obligations of periodic and commissioning inspections.

3 What is machine modernisation?

Modernisation of a machine in this connection means rebuild of an existing machine or machine group so that the lifetime of the machine continues as rebuilt, and the modifications made to the machine do not change essentially the purpose of use and properties of the machine. If the machine is included in the application area of the Machinery Directive, and it has been brought to the market or taken into use for the first time in the European Economic Area after the beginning of 1995, it has been, at the moment of start-up, subject to the requirements of the Machinery Directive including the requirement of CE-marking. After the commissioning of the machine, the safety requirements are mainly based on the Occupational Safety and Health Act and Work Equipment Directive, which do not include any procedures for proving the compliance with the requirements. Therefore, after the modernisation of an existing machine, it will not get any Certificate of Conformity or CE-marking.

In Finland, Act of the Conformity of Certain Technical Devices to Relevant Requirements (26.11.2004/1016) presents requirements also for modification and forwarding of existing machines:

9 § Responsibilities for persons supplying technical devices further

A person who supplies further a technical device placed on the market shall ensure that the device conforms to safety requirements in the same manner as it did when it was placed on the market. In addition, it shall be ensured that appropriate instructions in the Finnish and Swedish languages accompany the device.

10 § Existing technical devices

The provisions in sections 8 and 9 also concern, where appropriate, the sale, leasing and other supply of existing technical devices.

If a technical device is altered contrary to its intended purpose or in a manner otherwise essentially affecting safety, it will be treated as a new device and sections 4 and 5 will be applied to it. {4§, 5§ and 8§ apply to the indication of conformity of new machines}.

Due to the modernisation implementation, the safety level of the machine may not be decreased. In any case, the safety level may not remain lower than what the Work Equipment Directive obliges (for example Chapter 2). Even if the machine would have been taken into use according to the safety requirements of the Machinery Directive, it may be that, with time, there has been some development in the safety level, and the safety solutions of the machine have to be improved. In connection with the modernisation implementation, all documents necessary for the safety, such as operating and maintenance instructions, circuit diagrams and so on, must be updated.

So it is not allowed to make any official certificate of conformity, CE-marking or manufacturer's certificate of the modernisation. It is good that the executor of the modernisation implementation gives a written statement about what he has done and what requirements have been followed. For this purpose, an example of a safety description of a modernisation implementation prepared by an executor of a modernisation process is

presented in the Appendix B. A statement encourages the rebuilder of the machine to ensure safety, and in addition, it increases the credibility of the activity. The written statement also remains available for later use.

When estimating the extent of the purpose of use of the machine and related essential modifications, it can be based on the publication of the Ministry of Social Affairs and Health: Machine Safety – Regulations and application [9]). The publication is related to the old Work Equipment Directive, but the practice has not actually changed. According to this publication, the existing machine continues its lifetime as a modernised machine after, for example, the following modifications:

- replacement of parts
- refurbishment of the machine
- equipment of the machine with auxiliary devices
- increase of the machine speed or efficiency
- change of operating mode of the machine
- equipment of the machine with automatic control
- equipment of the machine with a new safety device

Correspondingly, the same thing applies to machine groups:

- Machine group remains old, even if machines included in it are replaced, if the purpose of use of the machine group is the same as before.
- If one part of a machine group is rebuilt by connecting a machine or a part of a machine to it, the group will not become new; it will be enough, when a risk assessment is performed on the rebuilt part and its connections with the other parts of the group, and the implementation is made by taking into account the results of the risk assessment, so that the final result meets at least the requirements in the chapter 2 of the Work Equipment Directive.

On the other hand, if the purpose of use of the machine is changed, or if essential modifications are planned for the existing machine, and this rebuild machine becomes maybe the central component of a new different machine, it is a question of construction of a completely new machine. In this case, the lifetime of the used machine being a component of a new machine is ended. Manufacturer of a new machine must follow all requirements of the Machinery Directive. All information about the parts taken from the existing machine which is necessary for construction and ensuring the safety of the new machine must be available (for example, if necessary, strength calculations and material information concerning the steel constructions, specifications of control systems including software documentation etc.).

The above mentioned applies especially to the production automation, in which case the purpose of use of the new automatic machine clearly differs from the purpose of use of the manual machine – for example when a manual lathe is the central component when constructing a new automatic lathe, or when an overhead crane is taken to be the central component of a new portal robot, etc. In these cases, operation mode and safety properties of the new machine differ essentially from the machine used earlier. [9].

The purchaser makes the decision about modernisation of an existing machine, or alternatively, about construction of a completely new machine. From the safety point of view, the difference between the definitions is not very big - the machine must in any case be safe and correspond to the regulations applied to it.

Several parties may participate in the modernisation process. However, only some of the following parties generally take part in the modernisation project: customer (payer), buyer, final user, management, project manager, designers (product development, planning, programming, testers, safety, etc.), specialists, technical experts, inspectors (safety, certification, audit, etc.), lawyers, authorities, professional organisations, different groups and representatives of suppliers of concurrent systems (for data transmission and cooperation). Each party has its own role, and on the other hand, some parties may also have several roles. There are certain tasks related to the role of the supplier and purchaser (employer), the implementation of which may be supported by other parties. [4]

Frequently asked questions

Questions:	**Answer:**
How to act in a modernisation, which is improving the safety, but the sufficient safety level is not achieved.	*Each party is responsible for safety within its own responsibilities and obligations. If it is noticed during the evaluation of the modernisation plan that the level achieved is not satisfactory, the plans must be changed to correspond to the requirements in the Chapter 2 of the Work Equipment Directive. It is not possible to avoid statutory requirements with agreements.*
The rebuilder notices that there are deficiencies in the safety of the object which are not included in his assignment. How to act?	*The purchaser is informed (in writing to make sure) about the deficiencies. If the purchaser does not undertake measures to eliminate the deficiencies, the deficiencies are mentioned in the documents delivered to the customer. The purchaser has the responsibility for the elimination of the deficiencies (obligation of the employer).*

Existing overhead crane is equipped with a programmable control unit to program the crane movements. Is it a question of construction of a new machine?

1. *If the crane structure remains the same and the control unit only replaces the earlier function, or a new function related to the earlier purpose of use is added, it is a question of modernisation of an existing machine.*

2. *Normally, the mode of operation and safety properties of a machine are essentially changed by automation. If the existing crane is used as a component in a new machine, which has a new type of function and purpose of use (for example a part handling robot of portal type), it is a new machine. Risk assessment and other measures presented in the Machinery Directive must be performed to the new machine.*

Safety must be ensured in any case. [9]

Paper machine producing newsprint is equipped with on-line coating station and calender.

In a machine line, the electric motor drives are replaced and the control logic is replaced by a new model or by a different kind of logic of another manufacturer.

It is a question of modernisation of the machine, and the machine must meet the requirements of the Work Equipment Directive.

It is a question of modernisation of the machine line, and the machine must meet the requirements of the Work Equipment Directive.

Platform palletiser in a wrapping line is replaced by a robot palletiser.	*The rebuilder and robot supplier must choose one of the two operation mode alternatives:* 1. *Modernisation of the machine line: platform palletiser in the existing machine group is replaced by a new but different kind of machine with the same function and purpose of use , i.e. robot palletiser. Manufacturer of the robot palletiser may deliver the palletiser robot as a final product, or 2 A machine, in which case, the robot palletiser must meet the requirements of the Machinery Directive applicable to it, or as a 2 B machine to be integrated to the machine group. The rebuilder of the machine group must in both cases ensure that the safety level according to the Work Equipment Directive is maintained.* 2. *New machine: If a robot is acquired for general use, in other words, a 2 B machine without any specific purpose of use to be integrated to the machine group, the constructor of the machine group must plan and ensure the safety, which means in this case, that the Machinery Directive must be followed.*
Two-hand operating control of an edging press is replaced by a safety device based on laser beams.	*It is a question of modernisation of the machine (modification). Modification of a type-tested machine is a demanding task, and in order to not jeopardise the safety, the evaluation of the modernisation implementation must be assigned to a specialist.*

4 Modernisation process

Phases of modernisation process

Modernisation process is here divided into nine different phases, and each of them includes tasks of the purchaser and supplier. In extensive projects, each phase may require dialogue between purchaser and supplier, but in all modernisation projects, however, these phases are shown at least on some level. But the quotation-order-agreement-path may also proceed directly to the agreement, without any separate order. Tasks of the phase require cooperation between the purchaser and supplier, and therefore, in this model, tasks of this part have been grouped together. Figure 6 presents phases of modernisation project in outline. Each phase

will be described more precisely later in this section. If deficiencies are observed in some phase of the process, some earlier completed phases must be redone.

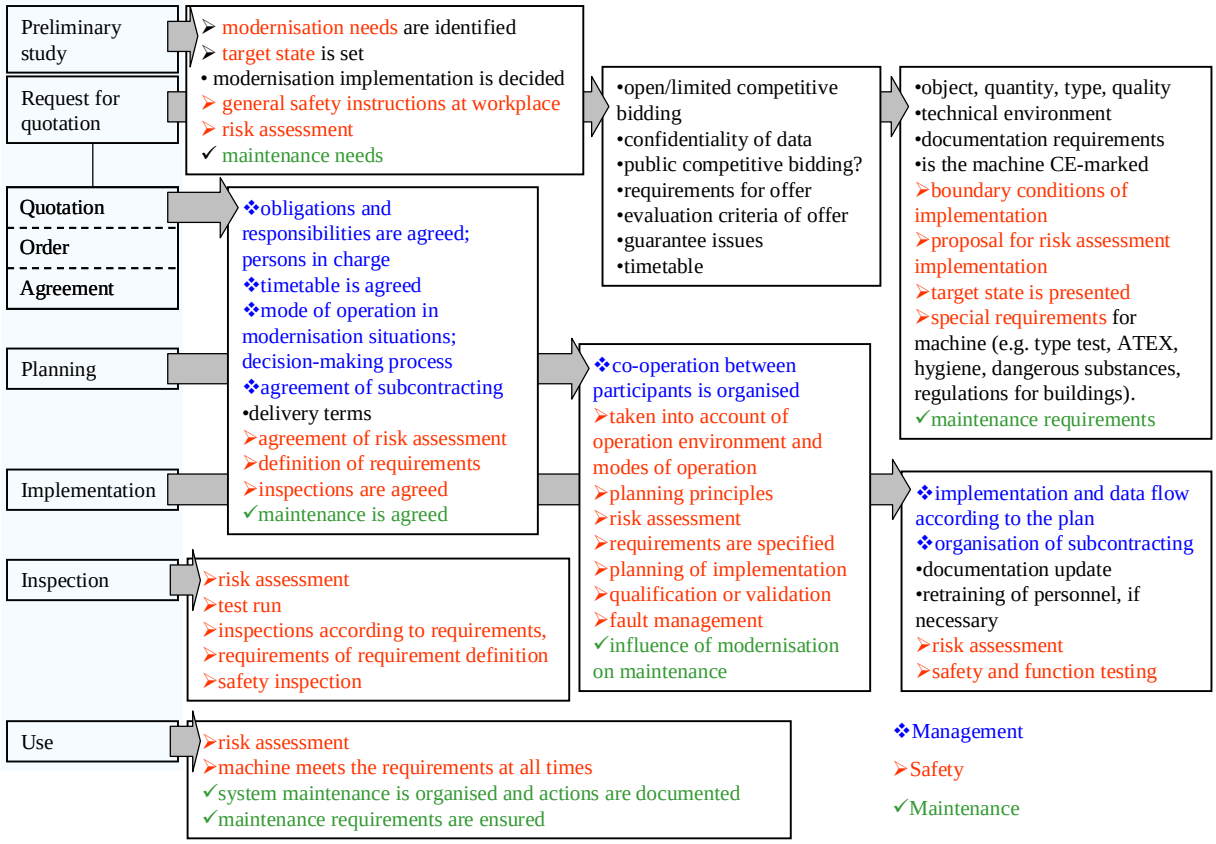

Figure 6. Model of the phases of a modernisation process.

Risk assessment is performed in different phases of the modernisation process. It is typical for the risk assessment that there is very little information in the first phases, and when the project proceeds, the amount of information increases and the risk assessment becomes more accurate. Therefore, it is important to organise cooperation and data transfer between all participants. In each phase, the risk assessment is performed for different purpose (cf. also Figure 7):

- In the preliminary phase of the study, the risk assessment is related to safe operating methods, and it is clearly the employer's responsibility. In this phase, it is studied, which risks of the old system are desired to be reduced. Risk assessment is also used to help in making the investment decision.
- In the quotation phase, the risks of different alternatives can be compared, and this comparison can be used as one of the criteria in the decision making.
- In the agreement phase, completing of a risk assessment and tasks of different parties are agreed.
- In the planning phase, a risk assessment of the risks caused by the technical properties of the machine is completed. The supplier's own experiences about other corresponding objects may be useful in this situation. Analyses related to the safe use will also be needed as soon as possible. In the planning, the risk assessment

should be used as one of the criteria in the decision making, when proceeding from one phase to another.

- In the implementation phase, the implementation and the plans are compared. At the latest in the planning phase, the users become a part of the evaluation process. Then, the user's point of view about the safe use of the machine can be seen more clearly.
- Before use, the employer's responsibility is to verify once again the safe use of the machine.

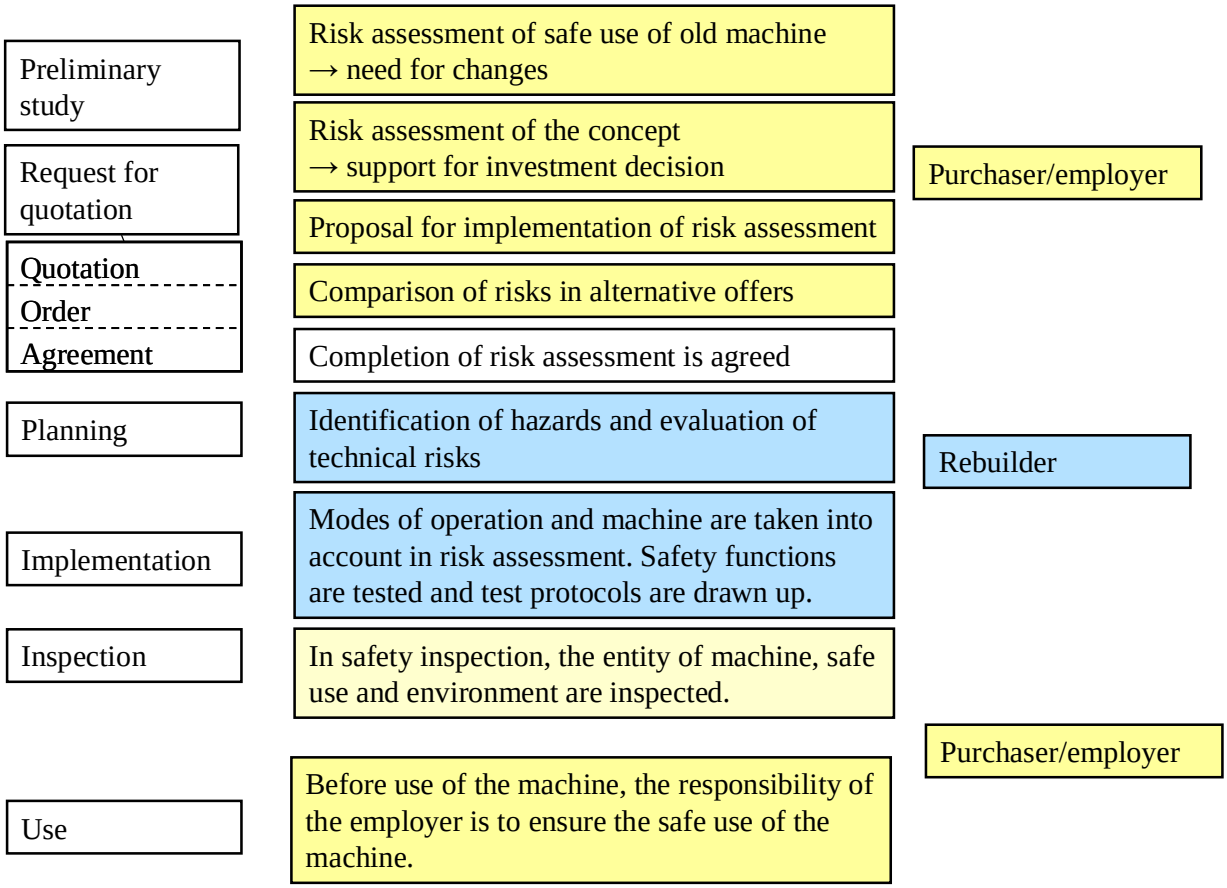

Figure 7. Common actions related to the risk assessment in different phases of a modernisation project. The party being normally responsible for the task is mentioned at the right side.

There is no need to start the risk assessment process in all phases from beginning, but it is worth using the results of the previous phase. Figure 8 presents common phases of a risk assessment process.

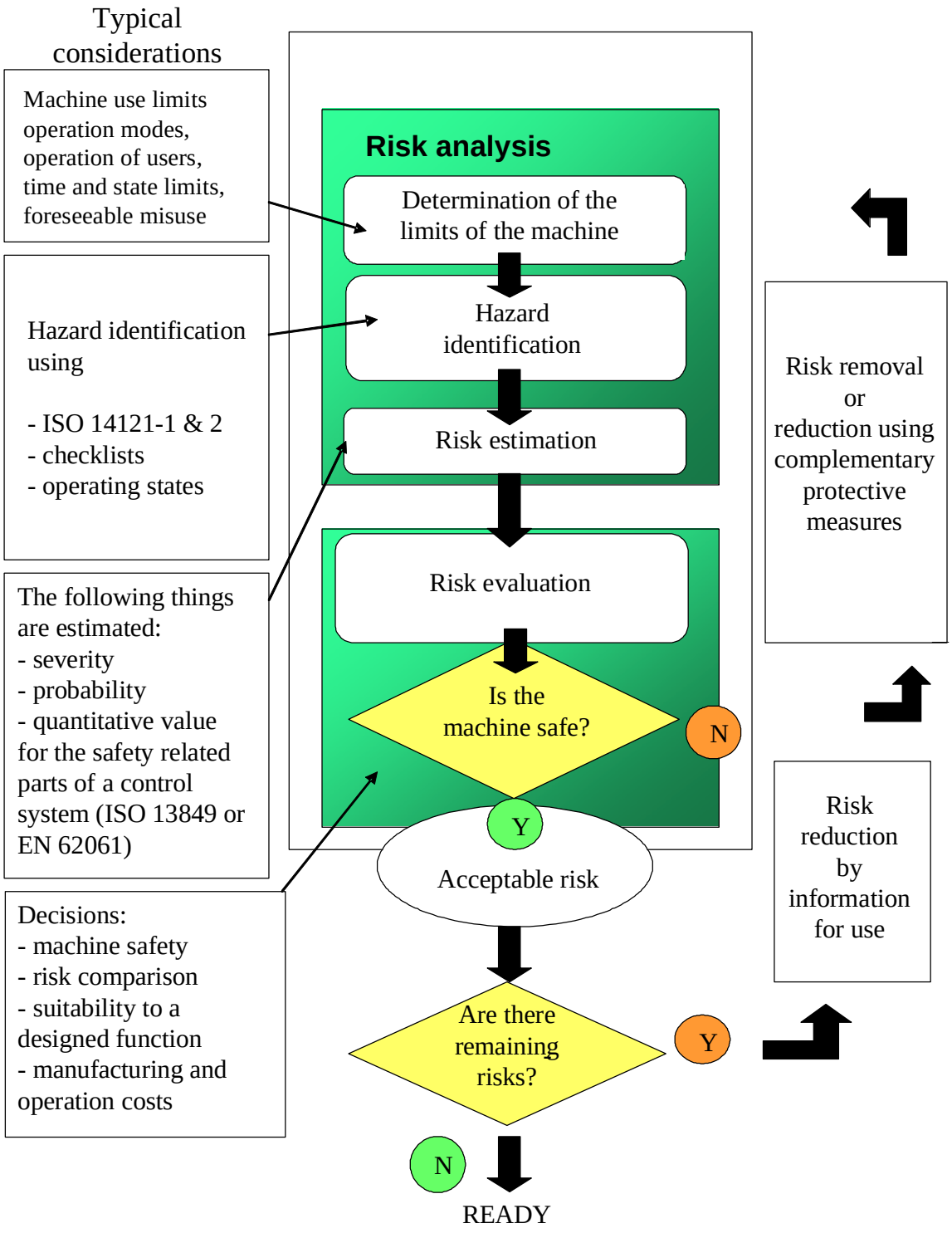

Figure 8. Phases of risk assessment.

If safety deficiencies are detected in the risk assessment, safety technical solutions must be planned for these objects. In the modernisation model, it is then possible, depending on the phase and the extent of the modification, for example, to add the modifications to the plans or to request for a quotation of the modification work. In any case, the modifications require negotiations. Deficiencies detected in the final phase of the modernisation process and their correction may be critical, because the approach of the promised delivery date may lead to

hasty decisions. It is necessary, however, to apply the same degree of focus on the modifications of the final phase as with all the other plans.

The following subsections describe the items to be implemented in each part-task and which one of the parties (purchaser or supplier) carries the principal responsibility for the part-task. Each phase of a modernisation project has a certain responsible party, but many things can be agreed also otherwise, and the implementation can be assigned to some outsider or sub-supplier.

4.1 Preliminary study

Objective: To make a decision on whether a modernisation project is needed.

Tasks of the purchaser

- Responsibility of the employer is to perform a **risk assessment**, indicating the safety of the use of the existing machine. This is good basic information for the risk assessment process of the rebuilt machine, which is started already in the preliminary study phase, even if there are many things that have not been decided yet.
- Data is collected from the representatives of different fields.
- Normally, it is necessary to explore different implementation possibilities by requesting information from eventual suppliers or **specialists.**
- It is explored, **which parts of the system need to be developed.** This is often related to the development of the production, new products, availability of spare parts and safety.
- Information about **problems** of the current system is explored.
- **Target state,** which is tried to be approached by means of technical solutions, is set. In the target state, not only the production is maximised, but it is also tried to reach a well-balanced entity with reasonable costs.
- The **needs of maintenance** are explored at the same time, when other development needs of the system are estimated. This includes preventive maintenance, corrective maintenance, clearing of fault situations and maintenance reliability.
- It will be determined, how much the future purpose of use of the machine differs from the purpose of use of the existing machine, and it will be decided, if **modernisation** of the existing machine is made, or if construction of a new machine according to the Machinery Directive is made.
- If the machine or machine group is included in the application area of the Machinery Directive (CE-marked, launched to the market or taken into use after

1.1.1995), the safety level of the Machinery Directive must be maintained, if the changes in the safety level do not require its improvement.

- General **safety requirements** of the modernisation object are presented. If necessary, a separate safety plan is followed in the modernisation project.
- **Decisions should not be made on the basis of insufficient information**, but the unclear items should be explored with specialists in an appropriate phase, when there is enough information available. Unclear items are consciously postponed to a later phase.
- At the end of the preliminary study, the purchaser makes the **investment decision.**

Tasks of the supplier or other expert

- Purchaser often needs outside expert help for the preliminary study. This may be related for example to the risk assessment, maintenance, determination of the target state or specific technical questions. Normally, the more extensive and complicated the system, the greater the need of technical support.

4.2 Request for quotation

Objective: Preliminary design is made to make a request for quotation, which urges the possible suppliers to make commensurable and comparable quotations.

Tasks of the purchaser

- Before initiating a request for quotation, it has to be decided, if the competitive bidding will be open or limited. If the eventual bidders are known, it is often worth initiating a limited competitive bidding. In some cases, general competitive bidding or public competitive bidding may bring more quotation alternatives. In the public sector, and for more extensive projects, a public competitive bidding is even mandatory.
- Competitive bidding also includes the confidentiality of the distributed information. Confidentiality is best ensured with known partners, and the next best, by using directed quotations, or by inviting the companies to competitive bidding.
- The object, quantity, type and quality of the purchase are always presented in the quotation.
- General description and technical environment, including the available space, availability of energy and connections with other devices, are presented.
- **Target state** is presented, in which the wishes and objectives influencing the choice of the quotations are expressed. The target state includes also the target state of the safety, but at this stage, all challenges related to the safety are not always

known, and on the other hand, there is not necessarily enough information about the safety technical solutions. This means that the expression of the target state is depending on the amount of information available. It can also be stated that the better the target state is expressed, the more accurate and comparable quotations are received.

- The targeted automation level and the boundary areas related to automation are presented.
- **Boundary conditions of the implementation** are presented, which may be related for example to the space available, time, the fact if the modification is implemented during the production run or safety requirements. It would be good to express clearly the boundary conditions of the implementation in order to avoid surprises later.
- The technical and functional **requirements**, as well as the requirements related to the environment and safety, are presented, as far as they are known. Generally, the requirements are related to availability, timing of the delivery, reliability, durability, accuracy, maintenance, data security questions and safety requirements.
- The purchaser's own standards and instructions are presented.
- **Special requirements** related to the machine, which can be, for example, data security requirements, type test requirements of the machine, ATEX requirements, hygienic requirements, dangerous substances or construction regulations, are introduced. Construction regulations may be for example the fire safety, emergency exit or air conditioning requirements or strength requirements for buildings.
- **Proposal for implementation of the risk assessment** is presented, indicating the procedures and implementing party for different parts, as well as how the risk assessment will be documented and which information the purchaser needs to himself. There are different kinds of practices for risk assessment and they are suitable for different purposes. Therefore, it should be considered, if the risk assessment is implemented by using the purchaser's or supplier's methods.
- **Maintenance requirements** are presented, which may be related for example to the maintenance places, maintenance intervals, availability of spare parts (delivery time for spare parts and for how long time the availability is guaranteed) and to rapid availability of repair services.
- **Requirements for documentation** are presented (which parts of the technical structure file are needed). In practice, at least an update of the instructions and technical documentation is needed.

- A wish for guarantee is presented. The supplier may have his own practice to offer guarantees.

- It is indicated, if the machine has been CE-marked earlier, in which case, the safety level according to the Appendix 1 of the Machinery Directive must be maintained. If the machine has been acquired before coming into force of the Machinery Directive on 1.1.1995, it must meet the requirements of the Work Equipment Directive. In the Work Equipment Directive, the requirements are more general, and when they are applied, the conditions at workplace are taken into account. The purchaser may propose that, when applicable, the safety level is increased in connection with the modernisation to correspond to the Machinery Directive. Sometimes, the conditions at workplace may also cause additional requirements (e.g. noise, ATEX, etc.). In this connection, also the standards that should be followed can be mentioned.

- Proposal for division of responsibility is made. Different participants have various practices for division of responsibility; this is influenced for example by the extent of the work and the each partner's share of the entity.

- Targeted timetable and delivery terms are presented.

- Factors related to the submitting of quotations, such as evaluation criteria, information concerning the submitting and validity of the quotation and the grounds for rejection of the quotation, and if necessary, the principle of price setting, are expressed.

Tasks of the supplier

- Suppliers may give information to the purchaser for preparation of an accurate enough request for quotation.

4.3 Quotation

Objective: To specify accurately enough, what is promised to be done and on which conditions. To answer the requests presented in the request for quotation.

Tasks of the purchaser

- The task of the purchaser is to give the potential suppliers sufficient information for submitting a quotation.

Tasks of the supplier

- It is described, what is quoted, and it is ensured that the items presented in the section "agreement" have been agreed in some document, if a separate agreement is not made.

- Deviations from the request for quotation are reported.

- Terms of payment and parties related to the quotation are presented.

4.4 Order

Objective: Order is a document, in which it is promised to implement the responsibilities of the purchaser. Order is often enough for smaller well-defined projects and no specific agreement is needed. This may depend also on company policy.

Tasks of the purchaser

- Comparison of the quotations.
- To order the entity specified in the earlier documents (request for quotation, quotation, records of negotiations, etc.) Instead of an order, also an agreement may be written.

Tasks of the supplier

- The supplier verifies that the order corresponds to the presented entity. If some item requires a confirmation, an order confirmation or agreement can be made.

4.5 Agreement

Objective: In the agreement, the obligations and responsibilities of the parties are expressed. The employer has the main responsibility. The party implementing the modernisation also has his own responsibility concerning the modernisation, as well as the manufacturer of the original machine concerning the original part of the machine.

Common tasks of the purchaser and supplier

- Terms of delivery, **tasks, obligations and responsibilities** concerning the purchaser, supplier, sub-supplier, manufacturer, consultant and inspector are agreed. Delivery and implementation can be divided into smaller entities being easier to manage. Timetables for the implementation are agreed.
- Publicity of the documents and also, what it is allowed to tell about the project to outsiders, are agreed. Data security questions, including for example the storage of data and communication methods, are also included in the subject.
- It is agreed, which documents the purchaser gives to the supplier (for making the assignment), and which documents the supplier gives to the purchaser (documentation of the performed work). These can be for example the agreed parts of the technical structure file.
- It can also be agreed that the safety of the modernisation implementation is expressed by a free-form **safety description of a modernisation implementation** (see Appendix B).

- **Implementation of the risk assessment**, cooperation related to it, tasks and documents as well as their delivery to the customer, **are agreed.** Principal performer of the risk assessment is often the party, who knows best the technology of the object and its risks. It must be agreed, which measures must be initiated based on the risk assessment and how high residual risks are accepted.

- **Requirement specification** is presented, in which the technical and functional requirements as well as the availability, reliability, environmental, space and safety requirements are expressed. In this connection, it can also be expressed, which safety requirements are followed, for example the Work Equipment Directive, Machinery Directive, voluntary requirements, such as standards, etc. Safety requirements are also obtained as a result of the risk assessment.

- **Implementations and responsibilities related to the special requirements** of the machine are presented, such as type test, requirements of ATEX state, hygienic requirements as well as the requirements related to dangerous substances and construction regulations.

- It is agreed, **what the different parties deliver to the technical environment.** This includes the space available, constructions, electricity, pneumatics, hydraulics and connections (user, device and other systems). It is important to agree the responsibilities of each area, and who organises for example the pressurised air or isolation of the power supply.

- **Requirements of the maintenance** are stated (see Request for quotation).

- Boundary conditions of the implementation are stated (see Request for quotation).

- Acceptance inspections are agreed.

- It is stated, if the machine is subject to official inspections, and who will take responsibility of them. Inspections can be for example the type test (Machinery Directive, Appendix 4), commissioning inspection (Work Equipment Directive) or periodic inspection (Work Equipment Directive).

- It is stated, how the test runs are conducted and who is responsible for which part of them. If material is needed for test runs, it is stated, who will deliver it.

- It is agreed, how the flow of information is carried out between different participants. This may include for example the distribution lists, persons in charge and speed of information availability.

- Decision-making process of the project is agreed, indicating the responsible persons and contact persons for different operations.

- Operation mode for expected surprise situations is agreed. This includes for example the limitations of cost liability. The modernisation implementation may for example prove to be more extensive than estimated, or new deficiencies related to the technology, environment or safety is observed during the planning process. There may also be delays related to the delivery, the handling of which shall be agreed. For this, an operation mode must be agreed in order to be able to handle quickly the eventual changes in the delivery.

- Necessary subcontracting is agreed, including for example what information concerning the sub-suppliers must be given to the purchaser in order to ensure for example the sufficient data security, quality and safety. Supplier audits can also be agreed, if necessary.

4.6 Planning

Objective: The planning is documented in writing, and the information necessary for the implementation is expressed in it.

Tasks to be agreed

- Cooperation between the participants in the project is organised. It is agreed that for example a group is organised, which will follow up and supervise the progress of the work.

- Risks of the object are evaluated during the planning. If new safety deficiencies are detected in the machine on grounds of the **risk assessment**, the parties shall be informed about them quickly. In the risk assessment, the following is taken into account: hazards caused by moving parts, noise and vibration data, electricity, hydraulics, pneumatics, radiation dangers, unexpected start, etc.

Tasks of the supplier

- Systematic planning principles and methods are used in the planning. These may be related for example to the quality system or standard. In the systematic method, all factors will be more surely taken into account than in the planning based on intuition.

- Operating environment and operation modes of the object are taken into account in the planning. These may have an influence for example on the degree of automation, user interface and walkways.

- **Risks of the modernisation situation** are taken into account. In the modernisation process, the risks may change and they may differ from the risks of the completed system. This is important, especially when the production is kept up during the modernisation. In that case, it is necessary to perform a risk assessment for each phase.

- **Customer requirements** are taken into account, such as clearing fault situations (target value) and the new properties of the system.
- It is worth phasing (dividing) extensive projects into entities being easier to manage.
- **Quality of the planning shall correspond to the purpose of use**. For example, objects being more demanding with respect to the safety need more attention than objects with no special requirements. More detailed information about the classification of control systems is to be found in the standards (SFS-EN 62061 and ISO 13849), and in machine-specific (C type) standards.
- **Requirements are specified** by taking into account the results of the risk assessment, relevant standards and other instructions, customer requirements, customer wishes as far as possible, and requirements of equipment manufacturers.
- Results of the risk assessment and residual risks are presented to the customer.
- The purchaser's own standards and instructions are taken into account.
- Implementation process is planned and validation plan (qualification plan) is prepared. Testing plans for the parts related to safety and the related testing protocols are drawn up.
- It is necessary to **go through** the common functions and residual risks together with the future users, especially when concerning special functions.
- The planned system is **validated**, i.e. accepted, according to the validation plan. This is often implemented in stages, so that the parts of the system are first gone through and analysed, and then tested. The verification is started from small entities and proceeds to more extensive entities (e.g. according to the V model).
- A plan for the fault management is made, including the actions and tools to eliminate faults. Also, it would be good to present some preventive actions in order to reduce malfunctions.
- It is presented, **how the system is maintained**, which parts must be inspected and serviced and who can perform the maintenance actions.

4.7 Implementation

Objective: The modernisation is implemented and documented, and if necessary, training of the personnel is organised.

Tasks to be agreed

- Implementation of the organisation and supervision of the subcontracting is agreed.

- **Retraining** of the personnel is implemented, if necessary. The purchaser is responsible for sufficient training of the appropriate persons, and the supplier, for its part, is responsible for the availability of the necessary material.

- The purchaser gives the **implementing parties sufficient information about the local safety conditions** and environment. This may have an influence on the safety plan of the implementation by the supplier.

Tasks of the supplier

- The implementation, as well as the flow of information, is completed according to the plan.

- **The documents are updated**, such as: operating, mounting, maintenance and safety instructions. For CE-marked machines, the update is performed in the technical structure file (if available), and for older machines, the corresponding design documents are produced.

- For modernised machine, the party implementing the modernisation may give a free-form **safety description of a modernisation implementation** (see Appendix B).

- **Factory tests are implemented (**Factory Acceptance Test, FAT) before the system is delivered to its location.

- In the location of use, **the safety equipment**, interlocking devices, alarms and safety functions **are inspected and tested** before the actual test runs, and the testing protocols according to the plans are drawn up.

4.8 Inspection

Objective: It is verified that the machine is ready to be taken into use. It is verified that it is safe to take the machine into use. The inspection must be documented in writing.

Tasks of the purchaser

- Inspections according to the requirement specification are performed. In this connection, also more extensive tests must be performed, so that all parties are present.

- If the delivery is subject to specific inspections, they are performed (for example the type test, commissioning inspection and so on).

- **Safety inspection** is performed, in which the safety of the object is evaluated by taking into account the entity, operating modes and environment of the system.

- The purchaser accepts the system to be delivered on grounds of the inspections on site. SAT (Site Acceptance Test).

- Timetable is established for necessary repair actions.

Tasks of the supplier

- Depending on the object, the supplier or the purchaser performs the test run according to the plan.
- It is ensured that the machine can be used according to the instructions.

4.9 Use

Objective: During the use, the employer must at all times ensure that the machine is safe to use. During the use, the maintenance actions and inspections are recorded.

Tasks of the purchaser

- The employer must take care that the work equipment meets the requirements applicable to it under the legislation. All machines must meet the **requirements of the Work Equipment Directive.** The earlier CE-marked machines must furthermore be on the safety level according to the Machinery Directive, unless the change of the system requires a higher safety level as it was at the moment of the start-up of the machine.
- Maintenance of the machine is organised and it is sufficiently documented.
- Prerequisites for the maintenance are created. Realisation of the requirements of the maintenance are ensured.

  The system is used according to the instructions. If the practice and instructions differ from each other, one or both of them or the technical structure must be changed.

5 Technical safety of machine

In the background of the safety of machines and machine lines, there is a systematic planning process and responsible safety management. These, however, are not sufficient for a safe implementation, but also information and know-how about the safety technical solutions as well as the use and properties of the machine are necessary.

Safety design of machines and systems is based on risk assessment and so-called three-step principle. With the risk assessment, the hazards are determined. Hazards are eliminated in the following order (see Figure):

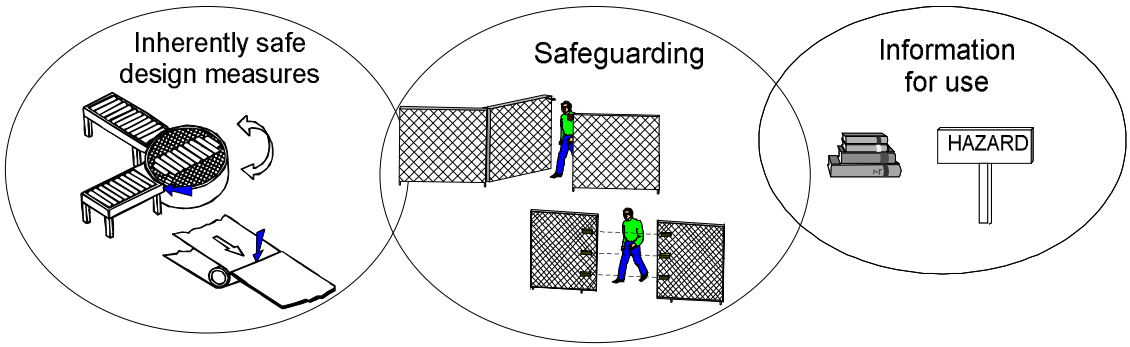

Figure 9. Safety design three-step principle. On the left, the nips have been designed to be less than 5 mm in size, so that there is no place for a finger. In the middle, the gate and photocells connected to the machine function stop the machine, if someone goes to the danger zone. On the right, operating instructions and appropriate signs are used to warn against hazards.

1. In the first place, it is tried to eliminate the hazard by means of design
2. In the second place, the safety is improved with safety technical solutions, and
3. In the third place, it is warned against the residual risk.

Hazards can be eliminated with structural means, for example by designing the nips and compression points so small that there is no place for a finger. With safety devices, the machine can be stopped before a person comes to the hazard point, or with guards, the hazard point can be kept completely out of reach. Warnings against hazards are given when the risk is reasonably low. The above mentioned means are used to try to avoid high risks.
All risks which may threaten the safety or health of people must be taken into account, and the risks must be eliminated, or they must be sufficiently reduced, with safety technical solutions. As a result of an inquiry to companies, certain risks and safety technical solutions related to modernisation process were found:

- **Safety distances and safety gaps** may change during the modernisation, because the size of the systems may change. If it is not possible to create a sufficient safety distance with safety devices (e.g. light curtains), guards and locking and opening protective housings (which do not open until the machine has stopped) can be used to separate persons from hazard points. If the safety gap (for example distance between a movable machine part and fixed construction) remains too small (the safety gap of human body is 50 cm, for example), besides the impact hazard, also the crushing hazard must be taken into account (consequences of crushing hazard are greater than those of impact hazard). More about this subject: [14], SFS-EN 999 The positioning of protective equipment in respect of approach speed of parts of the human body, SFS-EN 349 Minimum gaps to avoid crushing of parts of the human body, SFS-EN 294 Safety distance to prevent danger zones being reached by the upper limbs (ISO 13857 coming) and SFS Handbook 163 Application of protective equipment to detect the presence of persons.

- In old systems, **hazard points** are not often guarded according to the current requirements. Especially, it should be verified that persons are not able to reach zones with rotating parts, nips or quickly moving machine parts. Additional information: Occupational Safety and Health Act 2002/738, [17], [18] and [16].

- **Unexpected start-up** is the cause of considerable number of accidents at automation systems. Modernisation often affects the automation and start-up. Therefore, the unexpected start-up must be paid attention to. Additional information: [15], SFS-EN 1037 Prevention of unexpected start-up and SFS-EN 60204-1 Electrical equipment of machines.

- **Isolation of energy** both in modernisation phase and in actual use is a significant way to avoid unexpected start-ups. In complicated systems, a certain procedure may be connected to the isolation of energy to ensure absence of energy. As a general rule, however, it has to be tried to isolate the energies automatically by affecting for example the main switch or an emergency stopping device. Additional information: see previous chapter.

- **Stop and emergency stop** are important functions at the start-up phase after the modernisation. These functions should be inspected before start-up. When the systems expand, it may be necessary to divide the system to stop areas, which can be stopped without stopping the other areas. Additional information: SFS-EN 60204-1 Electrical equipment of machines and Work Equipment Directive [2] and [19].

- Requirements related to **start** have changed for old machines. In connection with modernisation, the start procedures should be updated. Additional information: see previous chapter.

- **Means of access** may be changed, or for example new maintenance objects may appear in connection with the modernisation. Additional information: SFS Handbook 93-5:2006 or 93-11:2010 "Safety of machinery. Means of access".

- **Deviation of the safety or automation level** or differences between control devices (location, operating principle) **in adjacent systems** may lead to dangerous situations. Persons working occasionally at both systems may at a certain specific point momentarily forget the required safety operation mode. User of the machine must at all times take care that the machines comply with the requirements. If there are important differences in the automation or safety of adjacent objects, warnings, training and limitation of work assignments may be necessary so that the employee's assignments do not continuously change between different kinds of systems.

- **Placement of** push buttons and other **control devices**, operating principles and colours must be made as uniform as possible throughout the mill. Additional information: SFS Handbook 93-4 "Safety of machinery. Electro-sensitive protective equipment" and 93-8 "Safety of machinery. Manual controls, displays, signals, safety signs".

- Often the causes and consequences of **failures** change, especially when increasing automation in control systems. Influence of the control system on safety often increases, and this must be taken into account in the design. Additional information: SFS-EN 954-1 (ISO 13849-1) and SFS-EN 62061.

- In connection with modernisation, the dangerous manual phases are tried to be eliminated as far as possible and replaced by automatic or mechanical functions, at which the persons are outside the immediate danger zone. This improves safety, even if the automation also brings **new risks**, such as unexpected start-ups.

During the implementation of the modernisation process, there are often new risks, especially when the modernisation work is performed with the machines running.

6 Summary

With modernisation of a machine or machine system, it is possible to make the existing machine more functional and safer to use than before. Successful modernisation project requires careful planning and cooperation between different parties. The best way to achieve this is to proceed gradually, so that in the preliminary study already, the goals are specified as far as possible. Too long-term decisions, however, should not be made at the beginning, if there is not enough information to support the decision making.

Besides the systematic management of the modernisation process, also different kinds of technical information related to the use of the machine and the level of current technology, as well as to the safety, reliability, availability and maintenance requirements, is needed. In this connection, the importance of the requirement specification shall be underlined, because it is exactly the insufficient requirement specification which has been the cause of a significant number of failed projects. Information is provided by eventual machine and device suppliers, authorities and research institutes. Appendix A contains a number of www sites providing additional information about requirements and safety issues.

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[23] Metalliteollisuuden Standardisointiyhdistys ry (MetSta). http://www.metsta.fi/

[24] Safety Technology Authority (TUKES). http://www.tukes.fi/

[25] VTT. http://www.vtt.fi/

[26] Finnish Society of Automation, Automation Safety Forum. http://www.automaatioseura.fi/

Appendix B: Safety Description for Modernisation of an Existing Machine

SAFETY DESCRIPTION FOR MODERNISATION OF AN EXISTING MACHINE

Metso Paper, Inc. Roll Finishing Systems
Wärtsilänkatu 100, FIN-04400 Järvenpää, Finland

Name and address of SUPPLIER OF MODERNISATION

assures that interlocking device is assembled to production line Y and

Delivery scope and identification (contract no and specification no).

is designed to be connected to winder (type X, CE marked and is first implemented 1999) gate control.

Identification of the old machine. If the machine is CE marked, this information appears on the paper.

The machinery to be delivered is manufactured so that it meets the technical requirements of the Work Equipment Directive (89/655/EEC) and its amendments (95/63/EC, 2001/45/EC).
Following standards were applied when the modernisation was designed:
SFS-EN 1034-1, -3

The most important used standards are listed here.

The standards SFS-EN 12100-1 and SFS-EN 12100-2 were followed in the design process.

The unit delivered has been installed and adjusted according to the manufacturer's instructions and is ready to be taken into operation.

Permission for commissioning must be evaluated separately every time. During evaluation, special attention is paid to the areas where the old machine and modernisation meet.

Place and date

In Järvenpää, the 1st of September 2009

Signature

Matti Mallikas

Matti Mallikas

Clarification of signature and position

Appendix C: Example of application of modernisation instructions to rebuild a paper manufacture line

In this case, for example the following rebuilds were performed on a paper machine: OptiHard calender, OptiCoatJet coating station, air devices, OptiSoft calender, OptiReel reel and Supercalender wind-up. The old winder was replaced by a completely new WinBelt winder. Figure C1 presents the machines and paper's run from one machine to another. Figure C2 shows the general view of a paper machine.
Devices to be mounted to the paper machine section were treated as rebuilds of an existing machine, following the requirements of the Work Equipment Directive. Safety level of the machine combination increased through the rebuild. Safety description of the modernisation implementation concerning the safety improvement actions for the rebuild was compiled.
The winder works independently, it was a completely new machine and was handled according to the Machinery Directive. A Declaration of Conformity IIA was given of the winder, and a CE-marking was made to it before start-up. This completely new winder will not be discussed more than this in this example.

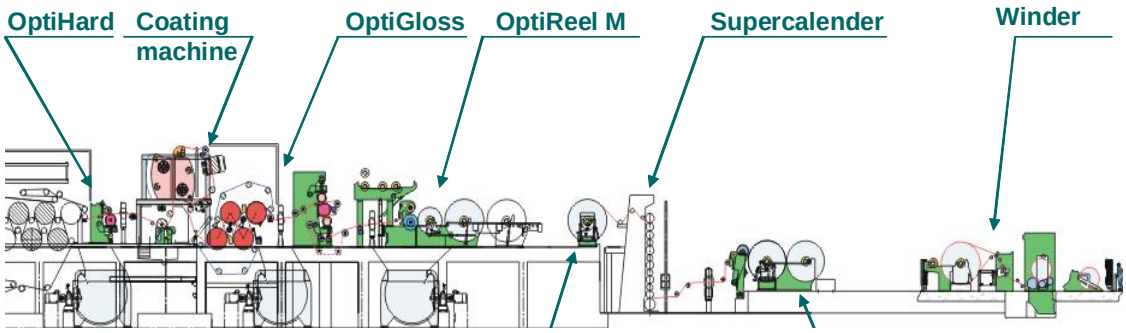


Figure C1. Principle drawing of the machines in the paper machine environment.

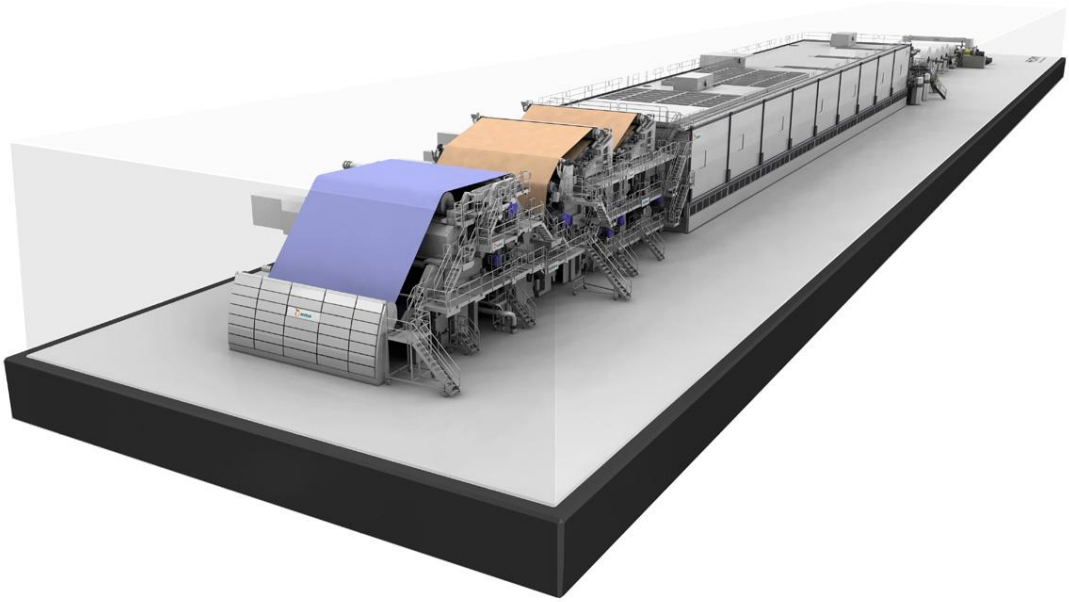


Figure C2. Paper machine.

Preliminary study

The modernisation need was estimated and the desired target state was defined by the purchaser. To support the estimation and specification, the risk assessment of the object was updated and used as a guide for the extent as well as the quality of the safety improvement actions. The information about the deficiencies and faults related to the process was collected. Check questions: Have all subareas been taken into account in the preliminary study? Does the risk assessment cover all work phases? Have the specific situations, malfunctions and "near-miss" situations at workplace been taken into account?

Request for quotation

In the formulation of the request for quotation, special attention was paid to the quoted functions as whole entities: subareas were clearly defined and they were not changed during the project. The existing safety state and also the new safety level set as a target were presented in the request for quotation. Information in the workplace risk assessment was used for the definition of the safety improvement actions.

- The technical and functional requirements, as well as the requirements related to environment and safety were presented as far as known.
- The purchaser's own mill standards and instructions related to safety were presented.
- Connection of the controls of the new functions to the old system was defined also for the connection points, and the program changes and additional interlocking devices were taken into account.
- Requirement for safety improvement method and safety documentation including the common inspections, risk assessments, instructions, informing about residual risks and safety analysis (cf. Appendix B) was presented.

Verification question: Have all essential facts concerning both the current situation and the future expectations been brought out?

Quotation

The quotation followed the scope and quality of the request for quotation. Eventual differences, if there would have been some, would have been clearly indicated as deviations from the request.

Verification questions: Will the sufficient safety level defined in the request for quotation be achieved with the solutions presented in the quotation? Have the eventual deviations been told?

Order and agreement

Information in the quotation and technical specification was collected to the agreement.

- Obligations and responsibilities were agreed.
- Operation mode for situations where it is necessary to change the assignment was agreed.
- It was agreed that concerning the paper machine, it is a question about a rebuild, and the winder is completely new.
- It was agreed that a safety description of the modernisation implementation is compiled for the rebuilds, and a Declaration of Conformity IIA for the winder.
- Timetable was agreed. Sufficient time was reserved for testing of the safety devices.
- It was agreed that the purchaser is the final assembler who will ensure the safety of the entity.
- Handling of the safety issues and co-operation meetings during the planning, manufacture and start-up were agreed. This point was considered to be very important.
- The documentation to be produced was agreed: Old instructions are updated, and new extensive instructions are compiled for the new parts.
- Share of the safety improvement in the delivery terms was agreed. It was taken into account that the safety equipment can not be tested until the machine has been completely mounted and tested.

Verification question: Have the target state, responsibilities, scope of the delivery and acceptance procedure of the delivery been clearly specified?

Planning

Requirements concerning the rebuild (Work Equipment Directive and, concerning the CE-marked machine, Machinery Directive) were taken into account. Essential standards and declared additional requirements (safety deficiencies and malfunction situations), improvements presented as proposals and safety level set as a target were taken into account.

Risk assessments of the purchaser and machine supplier were taken into account, their data were combined and they were continuously updated up to the end of the project. The supplier was taking care of the updating of the risk assessment. Risk assessments were different: that of the purchaser was based on work and that of the supplier on risk type. The data were combined by transferring the purchaser's data from the boundary area of the system to be rebuild to the risk analyses of the supplier. Different conclusions were discussed until a common opinion was found. Cost liability was defined according to the delivery limits.

Safety and handling of the machine were considered together in order to verify the safe use of the machine in different work phases. Both parties, purchaser and supplier, could provide useful utilisation experience for the going-through of the risk assessments.

It was ensured that the target state of the safety will be achieved with the means of planning.
The risk assessments were gone through: risks in the work phases, safety improvement actions and safety devices, and also very precisely, the residual risks and special instructions.
It was ensured that the old instructions were updated as far as necessary. Instructions for the rebuild included the information about the use and maintenance. Informing about residual risks is an important part of the instructions, and concerning them, a specific training event was held for the operating personnel.
Verification questions: Have the methods to improve safety, concerning the information transmission, been sufficiently handled together? Have the addition and changing needs been taken care of?

Implementation (installation at paper mill)
The safety devices were mounted according to the plans and completely tested before the machine was delivered to the users. The performed tests were written down in a test report which will also be used for the future regular testing performed by the user organisation. It was verified that all guards are in place. The condition of the electrification was verified with statutory measurements (SFS-EN 60204-1, Part 19 Testing and verification). Risk assessment was updated and the required measures, such as additional protections and instructions related to residual risk, were taken to reduce risks.
Verification question: Has the functionality of the plans been verified in practice?

Training
Training was an essential part of the machine delivery. Training is a part of every delivery. Correct method of use was instructed and the residual risks were made known. Work instructions were updated. Implementation of the training and the party being responsible for the training were agreed:

- The purchaser ensured the quantity, quality and understandability of the training.
- The supplier presented all essential information about the use and maintenance of the machine and made known the residual risks of the machine.

Verification question: Do the operating personnel know the correct method of use and are they aware of all residual risks?

Testing
Safety devices were tested when all technical mounting works had been completed. Safety device tests were not performed until all functions had been completed and the temporary solutions used during the start-up had been removed. The tests were performed as perfectly as possible: HW and SW separately, discharge of the voltages was verified by measuring, function of the gates and light curtains was tested device by device by affecting the safety devices. All tests were written down in a test protocol which was signed by the person responsible for the start-up.
All important facts affecting the safety were recorded in the test protocol: safety interlocks, stop function tests, fixed guards, safety gates and electrification measurements.

Liquefied gas devices require special attention regarding certificates and permits as well as mountings and training. Sub-areas of the training of operating and maintenance personnel are performing a risk analysis of liquefied gas equipment, going-through of safety systems at the construction stage, theoretical training in liquefied gas, process connections of liquefied gas system, alarm systems, measures to be taken in accident situations, liquefied gas fire-fighting practices in field in real situations, liquefied gas fire-fighting practices for fire brigade, training to inspect boundary areas of workplaces for maintenance personnel, liquefied gas equipment installation inspection, inspection by Inspecta and potential measurement of piping, normal inspection of piping, liquefied gas tank commissioning inspection and final inspection (TUKES).

In construction of the hot oil system, the following aspects were taken into account: placement and construction, regulations concerning boiler installations are followed in the boiler room, placement at outer wall, pressure discharge through explosion hatches to inner yard, bricklaying of service space windows located in the inner yard (elimination of risk of broken glass), safety distance to the next building, building is made of prefabricated reinforce concrete to be pressure-proof and the doors are made to open inwards, so that the pressure endurance prevents the explosion pressure from coming in to the paper machine hall.

General hot oil system protections: effective ventilation is made over-pressurised in the boiler room, boiler room electric devices + other devices are constructed according to the EX requirements, liquefied gas emergency disconnection occurs mechanically from outside the building, electrical liquefied gas emergency stop input by the door, oil leakage basin has no overflow (bottle basin), hot oil storage tank is located in the boiler room space and the boiler room is equipped with multi-zone sprinkler system.

Protections for the piping are as follows: normal piping with protective isolation in the basement section, piping isolated with plexi-guards at the end of the calender, piping area is sprinkled using hand triggering and the rolls are equipped with discharge valves for oil change.

Hot oil system inspections: Inspecta → liquefied gas system electrical installations, TUKES → liquefied gas system, Inspecta → pressure equipment system placement plan, acceptance and commissioning inspection of operation supervisors.

Commissioning inspection

In the inspection, it was verified that the machine, with all its parts, is ready and safe to be taken into use. Persons responsible for safety of both parties were participating in the inspection. Inspection reports and safety surveys concerning the modernisation were collected. The noticed minor deficiencies were corrected with temporary arrangements and a timetable was agreed for final corrections.

Test run

Only trained persons were accepted to the operator groups. Training of persons working shift work takes normally much time, but now, the operators were able to participate in the training as one group.

During the test run, the functionality of the safety solutions and the runnability of the machine were verified. Functionality and sufficiency of the instructions were verified in normal run, in fault situations and also in maintenance actions. During the test run, the machine was operated by operators from the supplier's as well as from the purchaser's side.

Special attention was paid to the compatibility of the safety functions and runnability. The discussion about operation experiences revealed slight overprotection - the machine had to be accessible in certain operating situations. Safety arrangements of the area were partly replanned: the gate can be opened under the agreed conditions and hazard points were separately protected in the danger zone.

It was verified that it is possible to use the machine according to the instructions (instruction and practice are the same).

Acceptance inspection (summary of the situation)
In the acceptance inspection, it was verified that the machine conforms to the specification in the agreement, that its safety level is higher than before and that it is ready to be accepted.

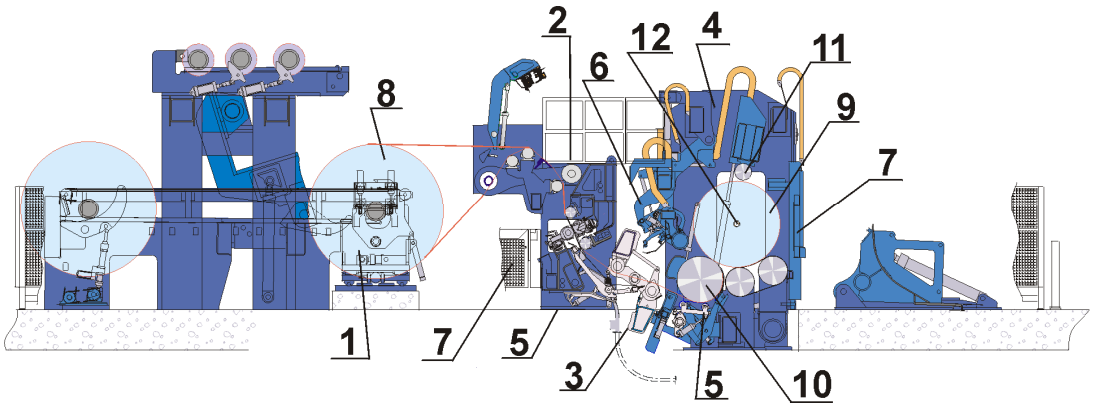
Appendix D: Rebuild of a winder control system

On the winder, the parent reels coming from the paper machine are slit into shipping rolls. Modernisation of a winder may be directed only at the control system, but often it also includes equipment that provides a higher level of automation, for example, splicing equipment, tail threading equipment, slitter positioning equipment and set change equipment. The addition of automatic functions generally results in the need for more protective devices. The object of **this example case** is a winder, in which, for example, the following parts were modernised:

- control system, user interface with a new PC and control logic
- position measurement of slitters and stations
- automatic paper splicing equipment
- slitter control measurement.

1. Unwinder
2. Automatic splicing
4. Wind-up section
5. Slitting section

Figure D1. Parts and structure of a winder.



Devices to be mounted to the winder part are treated as rebuilds of an old machine, following the obligations of the Work Equipment Directive. The safety level of the winder was considerably increased through the rebuild. A safety description of the modernisation implementation concerning the safety improvement actions for the rebuild was compiled.

Phases of the modernisation project:

Need identified in the preliminary study	Action and target state of the rebuild
- Improvement of the reliability of operation	→ rebuild and addition of the control system and field sensors.
- availability of spare parts	→ updating of the PLC and field sensors according to the current requirement level
- regarding the maintenance, an easier and quicker way to react in fault and malfunction situations	→ a system based on open international standard was chosen
- production intensification and quality improvement	→ automation level of the machine was increased: automatic splicing equipment, automatic roll discharge and protections according to the requirements of the risk analysis.
- need for replacement of safety photocells	→ safety photocells were replaced by new ones.

The customer had conducted a risk assessment which had focused on the winder operator's work and the risks related to the modernised automation. Operation mode of the winder was in many points changed from manual to automatic, which required additional protection and isolation of some areas.

Have the experiences of the operating personnel in usability and safety been paid attention to?

Do the plans include the purpose of increasing the automation level of the machine (machine modernisations)? What is the influence of the modifications on the modernisation to be implemented?

Request for quotation

Main parts of the target state of the rebuild:
- Siemens Simatic S5 PLC is replaced by Simatic S7F PLC
- modernisation of the positioning (slitter positions) and control of winding
- automatic splicing
- changes in safety caused by automatic roll discharge
- modernisation of slitter control measurement

- shutdown of 2 weeks in connection with the paper machine renovation
- hold-to-run function for front splicing (increase of safety level)
- WindHelp software to clear the special situations in the system
- instructions and training.

Demand for safety documentation was presented: Safety description of the modernisation implementation and risk analyses made during the rebuild project.

Quotation
After the discussion held on grounds of the request for quotation, the following main points were agreed to be the contents of the quotation:

- Simatic S5 PLC is replaced by Simatic S7 F series PLC.
- Existing bus cabling and I/Os will remain.
- Own ET200S stations, in which the standard and safety functions are combined, are made for the new necessary I/Os. The bus is directly connected via Profibus-DP bus to Simatic S7 PLC.
- New PCs are acquired for control room controls, the software will be WinCC flexible.
- New absolute encoders for positioning of stations and slitters, and the positioning is performed with the help of S7 positioning cards.
- Automatic splicing equipment (BJS) is implemented.
- Automatic roll discharge to the floor is added.
- Safety fotocell system to detect if the area is free and warning lights and traffic lights with monitoring diagnostics are installed. The customer had specified the area as a safety area according to EN 954-1 Category 4.
- The promised shutdown time is 7 days.
- Hold-to-run function (forced control) is taken into use.
- Change of the operating system is taken into account in the assignment.
- Emergency stop circuit is modernised (for example according to EN 954-1 Category 4).
- Channel-specific fault diagnostics from standard and safety function I/O → Events and faults can be fast visualised on the control panel.
- Safety circuit and sensors are visualised on OP panel and PC screen.
- Safety light curtain is mounted for slitter control measurement.
- Automatic tail threading is added at the desire of the purchaser.

Have the operating and safety experiences of the supplier been taken into account in the quotation and has the customer been informed about them?

Order and agreement
- Order was in accordance with the quotation.
- It was agreed that the purchaser is the so-called final assembler who will ensure the safety of the entity, and the supplier ensures the safety concerning his delivery.
- It was agreed that it is a question of a modernisation implementation of the paper machine and winder.
- It was agreed that a safety description of the modernisation implementation will be compiled for the rebuild part.
- Timetable was agreed. Time was reserved for testing of the safety devices.
- Handling of the safety issues (instructions and risk analyses) and the co-operation meetings during planning, manufacture and start-up were agreed.
- Documentation was agreed: the supplier took care of the instructions for the new devices, the purchaser updated the old instructions, and the residual risks were handled together. Some of the residual risks caused comments to the work instructions.

- Share of the safety improvement in the delivery and acceptance terms was agreed.

Planning

- Risk analysis → residual risks: it was verified that nothing essential had been left out.
- The drive was separated to be its own entity: hydraulic pumps' interlocks were dismounted from the drive and the winder was connected to be a part of the control system.
- Residual risks were gone through together with the customer and the operators. The customer accepted the plan.
- Drive interlocks were transferred to the safety bus.
- Emergency stop interlocks were updated to the drive to be in accordance with the requirements. The customer specified the safety level and supervised the drive supplier's work. (as mentioned above)
- Need for warning signs was estimated and they were acquired.
- Documentation of the electrics was entirely updated.
- Safety fences according to the risk analysis of the splicing equipment were added.
- New safety gates and old light curtains of the splicing equipment were connected to the safety cards of the PLC to be a functional entity.
- Safety monitoring was programmed in the PLC.

Verification that the old instructions are updated as deemed necessary, and the new instructions are sufficiently comprehensive.
Has something new come up with the planning and the new risk analysis? Have the eventual changes in the work methods and safety issues caused by them been discussed with the customer?

Implementation
- Work safety training organised by the customer for the workers implementing the modernisation during the work at the site.
- The customer was participating actively in the project → got acquainted with problems and solved them.
- Safety functions were installed according to the plans.
- Risk analyses were updated and the actions indicated by it were carried out: eventual additional protections and instructions related to the residual risk.

Training
In the training of the customer, special attention was paid to:
- safety functions
- danger zones
- separation of energies during maintenance works
- instruction in the correct method of use. The residual risks are communicated and the work instructions are updated.
- The supplier is responsible for the training for the operating personnel, and instruction in the safe use of the new devices.
- The maintenance personnal are instructed in how the energy sources of the machine should be disconnected, and in how to verify this. The maintenance of any new devices are also instructed, both with the help of the operating instructions and in practice.

– The operating personnel have been instructed with the method known as "hands on training".

Commissioning inspection

The commissioning inspection included the following:

- testing of the emergency stop circuit
- emergency stops of the drives
- testing of the emergency stops of the devices and testing of the resolution of the situation
- testing of the safety gates
  - all the new device documentation has been received
  - presence of all guards is verified
  - condition of the electrification is verified with statutory measurements
- completion and acceptance of protocols (e.g. safety device testing protocol).

Test run

During the test run, the functionality of the safety solutions and the runnability of the machine are verified. The functionality situations, as well as during maintenance work is verified. Verification that the machine can be used in accordance with and sufficiency of the instructions in both normal run and fault the instructions. It was verified that the instruction and practice correspond with each other.