Analysis Of The Degree Of Compliance With The EU Machinery Directive

Robert John Nicholas

Master Of Philosophy

THE UNIVERSITY OF ASTON IN BIRMINGHAM

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Summary

To date there has been little research undertaken to analyse the effectiveness of the goal-setting European Union (EU) requirements for the supply of machinery within the EU markets. This thesis attempts to stimulate interest in this area.

The findings contained within the thesis are derived from a large independent research programme conducted at Aston University. The research is designed to provide comprehensive analysis of machinery suppliers understanding of and compliance with EU requirements. The thesis focuses mainly on the EU Machinery Directive (89/392/EEC) as amended.

In this study seventy machinery suppliers to the United Kingdom (UK) market were surveyed between January 1995 and December 1998, in order to analyse the degree of their compliance with these relatively new requirements, which includes meeting relevant essential health and safety requirements (EHSRs), as well as other relevant product directives.

In addition a root cause analysis was undertaken in order to identify contributory causes for non-compliance with the EU Machinery Directive. This concluded that the contributory factors for non-compliance related to the role of risk assessment together with the lack of understanding and application of risk assessment.

Similarly, the analytical results indicate that there is wide spread confusion among machinery designers regarding the complex structure and the non-prescriptive nature of the European Normalised machinery safety standards.

Examination of the way risk assessment is presented by the key European standards has identified several inconsistencies and inaccuracies. This contributed to the high degree of confusion demonstrated by machinery designers.

The thesis develops a model, which demonstrates how health and safety can be integrated into machinery design.

Positive recommendations for change are discussed.

Key Words: -
Qualitative Research, EU Directive, EN Standards, Conformity Assessment, Essential Health and Safety Requirements (EHSRs).

Dedication

In memory of my mother Eva, who after a short illness died during this research project.

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Abbreviations

ACoP	Approved Code of Practice
ALARP	As Low As is Reasonably Practicable
AMTRI	Advanced Manufacturing Technical Research Institute
ANSI	American National Standards Institute
AUWED	Amending Use of Work Equipment Directive
BS EN	Transposed European Normalised - British Standard
BSI	British Standards Institute
CE	'Conformite European' meaning European Conformity.
EEA	European Economic Area
EEC	European Economic Community referred to as EU
EFTA	European Free Trade Area
EHSRs	Essential Health and Safety Requirements
EN	European Normalised Standard
EU	European Union
HSWA	Health and Safety at Work Act 1974
HSC	Health and Safety Commission
HSE	Health and Safety Executive
HTA	Hierarchical Task Analysis
IEC	International Electrotechnical Commission
ISO	International Organisation for Standardisation
LOLER	Lifting Operations and Lifting Equipment Regulations 1998

MHSWR	Management of Health and Safety at Work Regulations 1992
PES	Programmable Electronic System
pr EN	Provisional European Normalised Standard
PUWER '92	Provision and Use of Work Equipment Regulations 1992
PUWER '98	Provision and Use of Work Equipment Regulations 1998
SIL	Safety Integrity Level
SMSR	Supply of Machinery (Safety) Regulations 1992

Chapter 1: Introduction

This Chapter forms an overview of this thesis. It will elaborate the background to the research, the research question (research hypothesis), the research objectives, and the research methodology both from a philosophical and procedure perspective and will conclude with an overview of the thesis structure.

1.1 Background To The Research

The EU product directives made under Article 100A of the treaty of Rome are aimed at achieving the free movement of products in the European Economic Area (EEA) by removing different national controls and harmonising essential health and safety requirements (EHSRs).

The EU Machinery Directive 89/392/EEC as amended sets out EHSRs which must be satisfied before a machine may be sold in the European Economic Area (EEA). Products, which comply with this and other relevant directives, must be given free circulation within the EEA. Suppliers must ensure that their products, when placed on the market, comply with the legal requirements implementing the directives applicable to their product. A feature of these directives is that compliance is claimed by the manufacturer affixing a CE (European Conformity) marking to the product.

The Machinery Directive was implemented in the UK law by the 'Supply of Machinery (Safety) Regulations 1992' (SMSR), as amended. These Regulations apply to machinery that was first placed on the European market after 1 January 1993, although there was a transitional period until 31 December 1994 for the requirements to come fully into force.

To date four amendments have been made to the Directive and these will be discussed later in Chapter 2.

1.2 Research Question

In 1994 I commenced employment as a freelance health and safety consultant. I was asked by various clients to inspect and report on new machinery. This also involved questioning machinery designers/suppliers on their understanding of the EU Machinery Directive.

It became apparent that all of the machines supplied contained obvious hazards, which should have been eliminated or reduced at the design stage. Some of the machines had the 'CE' mark affixed, even though it is an offence to affix the 'CE' mark to a machine that is not in fact safe.

In addition during discussions with the suppliers, it became apparent that they were unfamiliar with the mechanism of how to demonstrate compliance with the

EU Machinery Directive, due to an overall lack of understanding on their part. The use of the term 'supplier' in this thesis also includes the responsibilities of designers, manufacturers and importers.

Until now traditional British Machinery Regulations and Standards have only placed an emphasis on mechanical hazards and physical safeguarding. The old concept that designers/ suppliers would provide a physical safeguard for a piece of machinery is like giving an answer to a question they did not know. The risk based approach to machinery safety, on the other hand, considers all hazards, who are exposed to them and then evaluates the risks. Subsequently it then decides on the most appropriate corrective/preventative measures, which are required in order to achieve adequate levels of safety and health.

I decided that it would be beneficial to research the extent of non-compliance with the EU Machinery Directive. Consequently I contacted the Health and Safety Unit at Aston University and was accepted on a higher degree programme.

1.3 Research Aim And Objectives

The aim of the research was to assess the degree of suppliers' compliance with the requirements of the EU Machinery Directive, implemented in the UK as the SMSR. In order to achieve this aim it was necessary to set out a series of key research objectives.

The objectives of the research are: -

1. To undertake a critical analysis of machinery related legislative requirements and standards, with particular emphasis on the approach to technical harmonisation.
2. To study the degree of suppliers' compliance with appropriate declarations of conformity and incorporation together with 'CE' marking requirements on a sample of machines supplied to the UK market between 1 January 1995 and 31 December 1998.
3. To review and analyse relevant EU directives indicated on the suppliers' declaration of conformity.
4. To review and analyse relevant EN transposed harmonised standards indicated on the suppliers' declaration of conformity and incorporation.
5. To examine the supplied machinery in order to determine whether they are safe.
6. To identify root causes for non-compliance with the EU Machinery Directive.
7. To develop a model which demonstrates how health and safety can be integrated into machinery design.
8. To make recommendations for change, where appropriate.
9. To identify further research opportunities.

The setting of objectives is of vital importance when undertaking research. In essence they guide the whole research process (Clark and Causer, 1991: 164).

1.4 Research Methodology

The research is primarily explorative and hence benefits from the use of qualitative research, which will be discussed further. The goal of exploratory research is to develop and expand as comprehensive and accurate picture of the area of the study as the prevailing conditions allow.

When undertaking research there is a requirement to be both structured and systematic, however this needs to "paired" with the flexibility to cope with unforeseen developments. "The key to successful research lies in combining a flexibility of response to changing circumstances with the maintenance of a coherent overall strategy" (Clark and Causer, 1991:163).

Within this section the philosophical perspective of the research is described as a series of six step sequences. These include: -

1. Rationale.
2. Methodological justifications.
3. Development of question set.
4. Recording of responses.
5. Familiarisation with the EU Machinery Directive and SMSR.
6. Pilot Study.

1.4.1 Rationale

This thesis is based on an association (through consultancy, training etc.), with a wide diversity of industry sectors. The names of these industries and their sector type will be explored in the section, which deals with the procedure for the research methodology (Section 1.5).

Access to the industries was granted to the researcher on the basis of health and safety consultancy contacts. The researcher was effectively given *carte blanche* within the industries to identify problem areas, due to the fact that they were all desperately keen to determine whether their machine purchases were in fact safe.

In January 1995 I decided to contact all existing clients (20 in total) in order to gauge whether they were interested in taking part in the research. Further discussions revealed that a total of 12 organisations were planning to purchase new machinery at this time and all of them were more than happy to take part in the research.

An analysis of the 12 organisations concerned revealed that they had a total of 425 machinery designers, manufacturers and suppliers, who during the last five years had supplied them with machinery and work equipment. The question was how many suppliers were contracted to supply new machinery between January

1995 and December 1998? Further discussions with the clients revealed that there were a total of 70 machines (from 70 different suppliers) on order during this period. It was decided therefore to use this 70 as a basis for the research.

Since it was not possible to examine technical files for all the machines, it was decided to start the investigation with an analysis of suppliers' declarations of conformity and incorporation. Once again these terms will be explained in detail in Chapter 3.

The declaration certificates can yield some useful information on the degree of understanding of the CE marking requirements, including the need to comply with EHSRs. The declarations also provide an insight into suppliers' abilities to identify other relevant EU Directives and apply relevant EN transposed harmonised standards (a term discussed in Chapter 3) to their machinery.

A smaller sample of 26 suppliers was then selected (from the original 70) for a more detailed analysis of the ways in which suppliers attempt to demonstrate compliance with relevant EU requirements.

One of the reasons for selecting these particular 26 suppliers was a relative ease of access to the machinery, documentation and suppliers personnel responsible for the EU compliance documentation. Other reasons included the analyst's familiarity with the above machinery through consultancy work, or training, and employers' willingness to take part in the survey.

The 26 suppliers, who took part in the second stage of the research, were then asked if they were prepared to take part in a semi-structured interview, in order to identify root causes for noncompliance with EU Machinery Directive. All 26 suppliers agreed to take part. The personnel interviewed were either the responsible person or someone who claimed to have an in-depth knowledge of the EU requirements.

The original intention of the research (to analise the degree of compliance with the EU Machinery Directive) was realised throughout.

1.4.2 Methodological Justifications

A qualitative research methodology was chosen for the study, for a number of reasons. Justifications for the selection of the research methodology were based both on the inappropriateness of quantitative research and the suitability of qualitative methodologies for the research topic (Allan, 1991:177-189). In addition discussions with my research supervisor, suggested that this was the most appropriate route.

Observation, as a data collection method, is essential to ensure all experiences are collected. The technique was used during the analysis of the declaration certificates, and in the inspection of the machinery. "Preliminary checks and referencing to the original source documents is an important stage in building up confidence in the data quality" (Holt, 1991: 261).

In addition it was necessary to ascertain whether the supplied machinery was in fact safe. In order to confirm this it was decided to adopt the task-based approach to risk assessment. Risk assessment is defined as a structured and systematic technique for identifying hazards, evaluating risk, and prioritising actions in order that risks can be eliminated or reduced to a tolerable level' (Raafat, 1996: 30).

A simple 'task-based' risk assessment of each machine, in accordance with the methodology developed by Raafat (1998), was undertaken as part of the verification process.

Task-based risk assessment has been derived from a variety of techniques known as task analysis. Task analysis is utilised to describe and evaluate, the human-machine and human-human interactions within systems (Kirwan and Ainsworth, 1992: 1). Task analysis can be defined as a study of what operating/maintenance personnel are expected to undertake, in terms of actions and/or cognitive processes, in order to achieve the correct operation of machinery. Task analysis can also document the information and control facilities used to carry out the particular tasks in question.

The level of risk identified by the task-based assessment was calculated utilising the risk calculator developed by Raafat (1996: 37). This risk calculator can be used as a tool to focus attention on risk levels, which are intolerable and therefore warrant further consideration.

Kirwan and Ainsworth (1992: 117) concluded the advantages of HTA included: -

1. That it is an economical method of gathering and organizing information, since the analyst needs only develop parts of the hierarchy where it is justified.
2. It enables the analyst to focus on crucial aspects of the tasks in question.
3. Each task element is only broken down into a limited number of sub elements, the analyst is provided with a convenient check that no task elements have been omitted at each stage.

Turner (1988: 108) comments that until recently the collection of qualitative research data was considered idiosyncratic and archaic. However the recognition of weaknesses in surveys and questionnaires has heightened interest in qualitative methods. Qualitative research is defined as research, which produces findings not arrived at via means of statistical procedures or other means of quantification (Allan, 1991: 177-189). Qualitative research methods may be used to uncover and understand what lies behind any phenomenon about which little is yet known.

A further advantage of this approach is that interviews are familiar to people and provide an accessible mode of data collection. In general terms people are happy to share theirs views, opinions and ideas.

The features of open questions within semi-structured interviews can be summarised as follows. They are flexible, they allow the interviewer to probe, they enable the interviewer to test the limits of knowledge, they encourage rapport and they allow the interviewer to make a true assessment of what the respondent really believes. Interviewers should use their knowledge of the topic under discussion to enable them to probe beyond the "yes" and "no" responses more common in survey interviews (Jones, 1991: 203-214).

"Interviewing is rather like marriage; everybody knows what it is, an awful lot of people do it, and yet behind each closed door there is a world of secrets" (Oakley, 1986: 231).

"In qualitative interviews the same topics must be covered for all respondents; every effort should be made to explore in similar detail each occurrence of significant phenomena" (Allan, 1991: 181).

Trevor Lummis (1987: 62) commented: “the art of good interviewing lies in being able to keep most of the interview conversational while following various digressions, remembering which questions the flow of information has answered and yet being prepared to question more deeply and precisely when necessary”. In conducting interviews it is of vital importance to retain a critical awareness of what is being discussed. The interviewer must be ready to explore some issues in greater depth (Jones, 1991: 204). Linda Measor refers to this as “listening beyond” (Measor, 1985: 63).

Another important aspect within the research methodology is that of reliability. “The reliability of data may well be enhanced if they are subjected to cross-checks and corroborations (Clark and Causer, 1991: 172).

From a personal perspective the disadvantages of this type of research methodology include the time-consuming nature and time limitations of the research process. Interviews are tiring and time consuming to conduct and analyse.

1.4.3 Development Of Question Set

The following points were incorporated into the question set, and are based on various guides to developing question sets e.g. Oppenhiem, 1992, King, 1995. It is important to consider the following: -

1. Always begin with general and interesting questions. This helps relax the interviewee and avoids responder set, i.e. giving an answer they think you want to hear.
2. Ensure that the question set is in a logical order, so there is no abrupt change of topic.
3. Develop probing questions in order to interrogate topics further and to illustrate certain topics. For example probes such as "Anything else", "What do you mean by that", "Could you develop that idea further", "Do you have specific examples", could be utilised to ground the data and remove potentially abstract responses.
4. It is important to avoid multiple questions, where more than one question is asked within the framework of the original question.
5. Questions should not be leading, that is those questions, which impose the researchers own view on the interviewee.

When utilising a semi-structured interview approach it is helpful to write the questions out in full. Although the interviewer may not use the questions as written, the exercise allows them to think about the way the questions could be phrased (Jones, 1991: 204).

The question set is discussed further in the Research Methodology – Procedure Section 1.5 and is highlighted in Appendix 3.

1.4.4 Recording Of Responses

It is necessary to decide whether to tape record the interviews or to write the responses down. Tape-recorded interviews have a number of advantages; these include accurate recorded material, the ability to concentrate on the framing of the questions etc. The disadvantages include the time required to transcribe the tapes, a noisy environment will be detected by the tape recorder and participants objections to being tape-recorded. Additionally it was noted that there was reluctance by many of the participants to be tape-recorded, due to a fear factor.

Note taking on the other hand is time consuming and can prevent follow up questions and probes. According to King (1995: 33-34), some participants find it flattering to have so much attention paid to them. Most people enjoy talking about their work. They appear familiar with interviews as a communication method, whether to share enthusiasms or to air complaints, particularly if the interviewer is an outsider. Above all else the interview process helps them clarify their thoughts.

The pilot study revealed that paraphrased note taking was the most appropriate for use in this study as it allowed for editing out the "umms" and "ahhs".

1.4.5 Familiarisation With EU Machinery Directive

The stage of familiarisation was an essential part of the research process due to the requirement to refine and develop research ideas and concepts. The familiarisation process involved a detailed analysis and took account of all of the requirements of the EU Machinery Directive and SMSR. This included the following: -

1. The Essential Health and Safety Requirements (EHSRs).
2. The technical file.
3. Conformity assessment.
4. Requirements of other EU directives.
5. Declarations of conformity and incorporation.
6. The 'CE' Mark.
7. The machinery is in fact 'safe', a requirement of the SMSR.

1.4.6 Pilot Study

The underlying reasons for conducting a pilot study relates to evaluating the proposed research process. Hence the purpose was to test three key aspects: -

1. An examination of the declaration certificates in order to identify relevant directives and transposed harmonised standards.

2. Inspection of documentation and machinery, to include task based risk assessments of the machines in order to identify hazards/potential hazardous situations.
3. A formal semi structured interview in order to test the question sets.

The use of pilot studies is a particular design issue for empirical investigations and is closely related to issues of research methodology. Clark and Causer (1991: 170) confirmed, “that a strategic decision has to be made about whether and to what extent to pilot or test drive particular research methods”. In this instance it was deemed necessary to test the research instruments, using a pilot study, in order to evaluate validity and reliability.

“It is important, particularly in the early stages of the interviewing period, to reflect upon the questions which you are asking and to amend them if necessary” (Jones, 1991: 205).

An evaluation of the pilot study confirmed that there was no requirement to modify the research design and methods.

1.5 Research Methodology - Procedure

Within this section the research procedure is described as a series of five step sequences. These include: -

1. The familiarisation process, in order to accrue sufficient knowledge and understanding regarding the requirements of the EU Machinery Directive and SMSR.
2. The development of question set and pilot study, in order to examine the extent of reliability and validity.
3. Inspection and analysis of declarations of conformity and incorporation. This was to assess the degree of suppliers' knowledge and understanding of the requirements of the EU Machinery Directive and SMSR.
4. Inspection of documentation and machinery - Task-based risk assessment, to assess if the supplied machines were in fact safe.
5. Semi-structured interviews, to identify root causes for non-compliance with the EU Machinery Directive.

The empirical research process was for a period from 1st January 1994 until the 31st December 1998. The researcher was registered as a part-time student. It was decided to wait until the 1st January 1995, to undertake both the pilot study and the main empirical research, due to the fact that there was a transition period before all aspects of the SMSR were fully enforced within the UK. The whole of 1994 was utilised for the familiarisation process and literature searches.

1.5.1 Familiarisation

During 1994 the intent was to become familiar with and proficient in all aspects of the EU Machinery Directive. This was achieved through a process of directed reading, seminars and discussions with my research supervisor. It included the following: -

1. An analysis of the EU Machinery Directive, The Supply of Machinery (Safety) Regulation 1992 and Key European Normalised machinery safety standards.
2. Attending a seminar on machinery safety –the risk based approach.
3. Discussions with my colleagues at the Heath and Safety Unit at Aston University.
4. Reviewing of books, articles and publications.
5. Reviewing and analysing a wide diversity risk assessment techniques.

1.5.2 Development Of Question Set And Pilot Study

A total of 10 suppliers took part in the pilot study. The question set was derived from an analysis of the requirements of the EU Machinery Directive, the EN machinery safety standards and finally aspects of the designer, manufacturers and suppliers perceived management systems. The question set is shown in Appendix 3.

This question set was shown to peers and academic members of the Health and Safety Unit at Aston University, together with all other interested parties. Their comments were incorporated into the finalized version.

1.5.3 Inspection And Analysis Of Declaration Certificates

Seventy suppliers (see Table 1.1) of machinery to the UK market were selected to represent a cross section of industries and machine types. The machines had been placed in a wide range of industrial sectors and company sizes, from small enterprises to large multinational organisations.

Analysis of Table 1.1 indicates that the 70 suppliers are from wide diversity of industrial sectors. The new machinery was supplied between January 1995 and December 1998: -

Table 1.1 Industry Sector And Number Of Machines

Industry Sector (Machinery Users)	Number Of Machines
Aluminium Processing (Alcan Chemicals)	1
Motor Vehicle Manufacture (IBC Vehicles/Vauxhall Motors)	21
Automotive Components (Standard Products/Textron)	22
Distilleries (United Distillers)	2
Food Processing (Cargill)	1
Tobacco Manufacturing (British American Tobacco (BAT))	3
Ceramics (Automated Transfers)	1
Offshore Oil and Gas (Eastern Trough Area Project (ETAP)/ British Petroleum Exploration (BPX))	18
Paper Printing (Mackays PLC)	1

In addition, field visits were made to the premises of the following suppliers: -

1. North Sea Compactors: Forties Supplier - Aberdeen.
2. Noble Engineering: Forties and British Petroleum Exploration (BPX) - Aberdeen.
3. Automated Transfers: Ceramics/Potteries - Stoke Upon Trent.
4. Van der Lande: British American Tobacco (BAT) (Material Transfer Equipment) - Netherlands.

The majority of suppliers sampled in the study were based in the UK. However, the sample also included suppliers from other EU member states, and a smaller number from outside the EU.

Table 1.2 UK Suppliers

Country Of Supply	Number Of Suppliers
UNITED KINGDOM	36

Table 1.3 Other European Member States

Country Of Supply	Number Of Suppliers
ITALY	11
GERMANY	10
NETHERLANDS	3
NORWAY	2
SWEDEN	2
SPAIN	1
FRANCE	1
BELGIUM	1
	31

Table 1.4 Outside European Union

Country Of Supply	Number Of Suppliers
USA	1
CANADA	1
JAPAN	1
	3

An analysis was undertaken of the requirements of both a declaration of conformity and declaration of incorporation. From this analysis a template was developed which indicated all of the EU requirements for declaration certificates. These are shown in Appendix 1 and explained in detail in Chapter 3. In addition, the differences between the declaration of conformity and incorporation are also explored in Chapter 3.

The inspection and analysis of the declarations of conformity and incorporation considered the following: -

1. Compliance with declaration and marking requirements.
2. Compliance with relevant directives (only a requirement on declarations of conformity).
3. Awareness of relevant harmonised standards.
4. Analysis of year of supply.
5. EN standards most frequently cited.

The words 'complete', 'incomplete' and 'none' were used in order to analyse relevant directives and EN machinery safety standards shown on the declarations of conformity/incorporation. A 'complete' declaration would be one, which indicated all relevant directives and EN standards appertaining to the machinery. An 'incomplete' declaration on the other hand would have omitted certain directives and EN standards. The word 'none', was used to identify declarations, which made no reference to relevant directives and EN standards whatsoever.

1.5.4 Inspection Of Documentation And Machinery – Task-based Risk Assessment

The second stage of the study singled out 26 suppliers for a more detailed analysis of the route of compliance with the EU requirements. This included physical inspection of both the documentation and machinery to verify if the machines were in fact safe and to determine the level of residual risk.

The analysis involved the inspection of documentation for each machine to assess the degree of compliance with relevant harmonised standards, and the standard of instructions for safe access during normal operation and other foreseeable activities, such as maintenance, testing, fault finding, setting and cleaning. Particular attention was afforded to instructions and documented procedures for safe commissioning, as many safety systems may have to be defeated at this stage for 'inching', start-up and adjustments.

The last stage of this section of the analysis involved the physical inspection of individual machines, including the level of integrity of the safeguards, interlocking devices, electrical system, emergency stop devices, safety-related parts of control systems and other safety devices. These were identified as key aspects of the EHSRs.

It was at this stage that the task-based approach to risk assessment was utilised. Raafat (1998: 60) concluded that 'the task-based approach to risk assessment is highly recommended due to its open ended nature. The approach is both logical and imaginative and critically examines the adequacy of existing risk control measures. The degree of detail for this type of analysis will depend on the complexity and criticality of each task, as well as the nature of the hazards'. In order to apply the task-based assessment, it is essential to identify all of the tasks involved in operating, maintaining, and setting, adjusting and cleaning the items of machinery.

A task-based risk assessment worksheet was utilised for the machinery inspections. In addition pro-forma was developed in order to record and analyse the research findings. These are shown in Appendix 2.

The risk calculator (Raafat, 1996: 37) was used as a tool for screening of the risks inherent in the machinery. The risk calculator is intended as a rapid guide to evaluation of the risk levels e.g. high, medium and low risks. It is of vital importance to determine the risk level, in order to assess, whether the machinery safeguards and safety devices are compatible with the level of risk identified.

An example of the risk calculator is shown in Appendix 2 and a full explanation of the technique is contained within Chapter 6.

1.5.5 Semi-structured Interviews

The reasons for the use of the semi-structured interview approach were discussed in detail in Section 1.4.

The 26 suppliers who took part in the inspection of documentation and machinery section all agreed to take part in the semi-structured interviews. The key objective of the interviews was to identify root causes for non-compliance with the EU Machinery Directive.

The interview questions together with a pro-forma for the collation of responses are shown in Appendix 3. The questions and pro-forma revolved around three key areas: -

1. The EU Machinery Directive.
2. The EN harmonised standards.
3. Designer, manufacturer and supplier management systems.

It was necessary to observe interview protocol at all times. Consequently at the start of each interview, participants were briefed on the purpose of the interview. They were assured anonymity (i.e. that interview data could not be attributed to an identifiable individual), to avoid fear of reprisals, or subjects having to toe the company line and giving answers they assume are required.

Interviews took place on the premises of the particular industry sector, with the exception of the field trip visits. The interviews varied in length according to the individual interviewed. The interview notes were transcribed (para-phrased) during the interview.

1.6 Thesis Structure

Chapter 2 contains the literature review, which encompasses a critical review and analysis of legislative requirements and standards, regulatory compliance and the concept of integrating health and safety into machinery design process.

Chapter 3 examines the route to demonstrating compliance with the EU Machinery Directive.

Chapter 4 examines the degree of compliance with all aspects of the EU requirements and Chapter 5 identifies root causes for non-compliance.

Chapter 6 contains the discussion of the results from the empirical research findings.

Chapter 7 develops a model, which demonstrates how health and safety can be integrated into machinery design.

Chapter 8 indicates the conclusions from the empirical research, and sets out key recommendations for change.

Finally Chapter 9 identifies future research opportunities.

This Chapter has covered the background to the research, the research question and objectives. In addition it has examined the research process and has justified the research method and has concluded with an overview of the thesis structure.

The thesis will now move on to undertake a literature review.

Chapter 2: Machinery Safety Literature Review

This Chapter contains an examination of the current literature available with regard to machinery safety, lack of compliance and the integration of health and safety into the machinery design process. The review began with an in depth search for suitable material which was pertinent to the research question. It included searches of the British Library, the index to theses covering machinery safety and on line databases such as the Edinburgh Engineering Virtual Library, which can be accessed via the World Wide Web.

The literature review contains the following sections: -

1. The reactive approaches to machinery accident prevention.
2. Safety integration into machinery design.
3. The legislative framework.
4. Prescriptive machinery legislation.
5. Compliance with legislative requirements.
6. European union regulation.
7. The risk-based approach to machinery safety.
8. The transposed EN standards.
9. The DTI study on impact of EU Machinery Directive.

2.1 The Reactive Approach To Machinery Accident Prevention

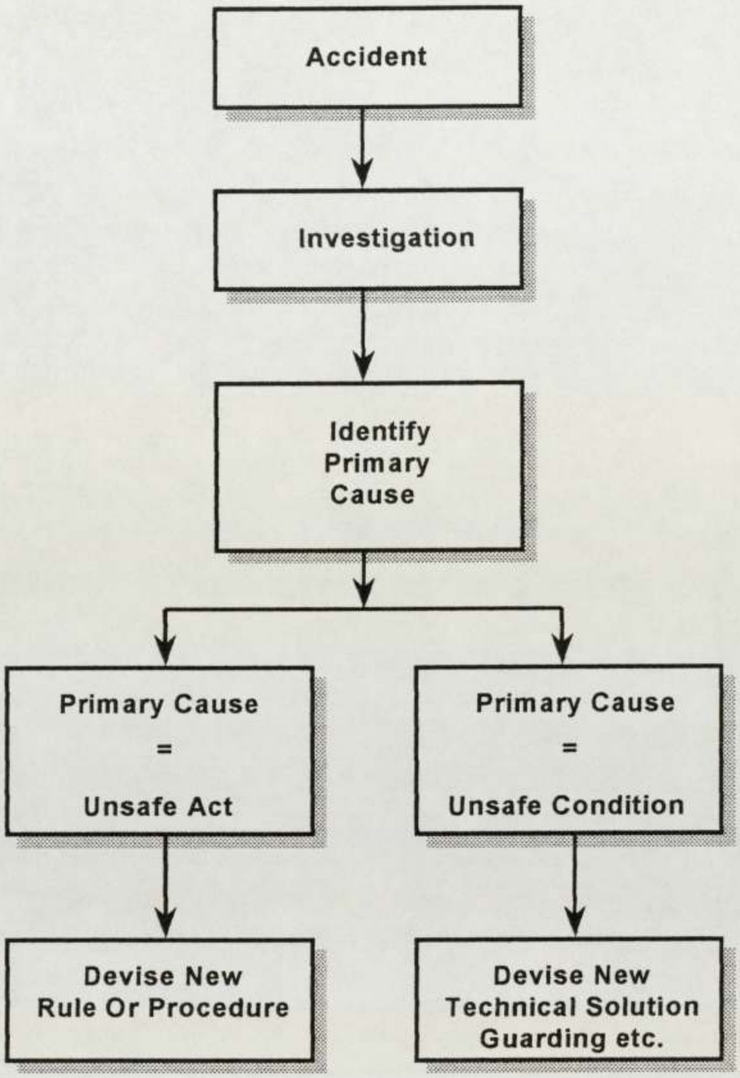
The traditional reactive approach to machinery accident prevention was essentially retrospective and focused mainly on incidents or accidents, which had already occurred.

Figure 2.1 illustrates the traditional approach to machinery accident prevention, where the investigation of incidents or accidents tended to concentrate on primary causes in terms of unsafe acts, such as operator and maintenance personnel not following procedures, or unsafe work conditions such as the failure of machine safeguards.

The reactive approach consisted of an attempt to manage machinery risks by the introduction of additional safeguards or new procedures following an accident, in order to prevent a repetition of the same accident (Booth, 1993b).

The reactive approach to health and safety has been found to be substantially wanting in the increasing technological environment. Waiting for an accident to occur and then attempting to prevent its reoccurrence, is fundamentally flawed. It is nothing more than mopping up after the event.

Figure 2.1 The Traditional Approach To Machinery Accident Prevention



Source: Adapted From Booth (1993b)

Instead organisations should actively seek to identify hazards and evaluate risks. This way, control measures could be put in place before accidents occur, not after their aftermath.

A summary of the limitations of the reactive era is as follows: -

1. The approach is reactive and driven by accidents, which have already occurred. It tended to prevent only those accidents with a similar set of primary causal factors.
2. The 'Pareto' effect (80:20 rule) suggests that 80% of accidents occur as a result of the same 20% root causes (Raafat, 1998: 5). In effect, the underlying facets which were responsible for the accident. Unless these root causes are identified and controlled, accidents can continue to happen. The objective of a structured accident analysis is to identify these root causes and eliminate all accidents associated with a common root cause, not just a repetition of the same accident.
3. Latent failures resulting in poor equipment, machinery and safety systems as well as management system errors are often inadequately addressed.
4. Low probability accidents with severe consequences are usually not considered by this approach, since there is no history of such accidents.

The findings of a study on 661 machinery accidents (HSE, 1983) have shown that: -

1. Machine operators were the group at greatest risk of injury from contact with moving parts of machinery (65 per cent), although they were the least likely to sustain major injury. The most significant activities resulting in the injury were unplanned cleaning and clearing blockages (i.e. maintenance type activities).

2. Most accidents occurred on machinery provided with some form of physical safeguard or safety device (74 per cent). It was found in 39 per cent of the cases studied, the guard was ineffective in preventing the accident. Over 44 per cent of the guards provided were fixed guards and were either ineffective or easy to defeat.
3. Over 90 per cent of the accidents were reasonably foreseeable.

Although these findings may be regarded as general, they illustrate that the provision of safeguards will not always make a machine 'safe'. Not only may they be poorly designed, but also certain activities may necessitate the removal (or defeating) of safeguards. Such activities should be identified by means of a structured risk assessment.

2.2 Safety Integration In Machinery Design

The mass introduction of new technology into the industrial production engineering and management arena has resulted in an increase both in automation and information technology systems. These in turn have resulted in dramatic improvements in terms of quality, productivity, flexibility and availability. However, by virtue of their complex nature they create certain difficulties, which must be addressed at the design stage.

These include:

1. The conceptual stage of the design, where it can be difficult for the designer to take into consideration all of the necessary factors relating to the integration of health and safety into the machinery design e.g. operator/maintenance intervention, setting, adjusting, tool changes, fault-finding, installation and commissioning, decommissioning and disposal etc.
2. The execution phase of the design, where designers have to move away from the conceptual framework and consider whether risk elimination and risk reduction (for all of the health and safety factors noted above) has been achieved in practice.

Analysis of these industrial situations often uncovers large differences between the predicted performance of systems and those observed in practice. These include the management of deviations, constraints of production, extending the life of equipment, evolution of production systems, process variability, etc. This gap is considered currently as one of the main causes, not only of poor performance, but also of risk taking by operators/maintenance personnel, who have to respond to situations, which have not been considered in the design phase (Fadier, Ciccotelli, 1999).

The integration of safety and human factors into the design phase is therefore fundamental if high levels of performance are to be realised. It was found that the vast majority of work carried out in the area of design, relates to practical experience and not to any perceived theoretical basis (Wagner 1988: 96-112). Although different researchers have tackled a wide diversity of design problems, the problem of integrating health and safety into the machinery design remains a scarcity.

Research undertaken to date has tended to review and analyse the various tools, methods and approaches to design, or have offered new research or design methods (Fadier, Ciccotelli, 1999: 79-84).

The concept of a model for integrating health and safety into the machine/process design has been developed around simple consumable products, where the users themselves are the consumers. However, if the product is a complex production system, modeling should be based on the foreseeable requirement for human intervention. A structured and systematic risk assessment would aid this process and risk assessment.

Designers are faced with several problems during the design phase. These include the following: -

1. The lack of adequate data relating to new innovations, creative designs and even in routine design.
2. The inability to foresee the differing requirements for human intervention, and the hazards associated with each activity.

3. Identification of intended use and foreseeable misuse by machine users, particularly in tasks relating to maintenance, setting adjusting and faultfinding etc.
4. The marriage of several types of expertise, which makes both the resolution of the problem and communication between these parties more complex.
5. Design conflicts between different disciplines: mechanical, electrical and control systems, which must be effectively managed.

In order to define a product, an information model must first be considered. This will include such things as geometric, functional, technological, physical, logistic, economic and social aspects, etc. This will ensure the control of conformity with the initial specification after manufacture. This model must serve as the basis for all aspects of information exchange. In addition, it must be capable of being integrated into the product-engineering environment.

Research undertaken by Bernard 1999, Belloy 1994, Constant 1996, Chapa Kasusky 1997, Harani 1997, Sellini 1999 and Eynard 1999 have considered a wide diversity of design models. However, none of these considered the integration of health and safety into the machinery design. A model for integrating health and safety into machinery design will be explored in Chapter 7.

2.3 The Legislative Framework

The requirement for legislative intervention has been recognised since the passage of the early Factory Acts. Legislation developed in a piecemeal manner in response to particular trade union demands and public concern (Wedderburn, 1986: 413).

The plethora of legal regulations and statutes indicates acceptance of state intervention to ensure a healthy and safe working environment (Bach, 1994: 123). Nonetheless this has neither dampened controversy about the most appropriate type of regulation nor has it diminished the debate about the existing legislative framework.

The current UK regulation of the working environment stems from the 1972 Robens Committee Report on Safety and Health at Work (Robens, 1972). The ensuing legislation, the Health and Safety at Work etc Act 1974, was closely modelled on the Robens recommendations. One of the features of this report was the diagnosis that apathy was the cause of accidents, the report also contained an argument in support of the view that the existence of a mass of complex regulations encouraged reliance on state regulation and discouraged individuals from taking personal responsibility.

The committee believed that the amount of law was counter productive and advocated in its place a system that would place the primary responsibility for improving health and safety with those parties who created the risks.

2.4 Prescriptive Machinery Legislative Requirements And Standards

2.4.1 The Factories Act 1961

Under the Factories Act 1961, the responsibility of 'fencing' dangerous parts of the machinery rested with the employer (end user). For example Section 14 of the Factories Act 1961 states that "every dangerous part of any machinery...shall be securely fenced".

In addition sellers and hirers of machines shall ensure that "every set screw, bolt or key on any revolving shaft or spindle, wheel or pinion, shall be so sunk, encased, or otherwise guarded as to prevent danger..." (Factories Act 1961, s17).

The dangers against which fencing is required have received significant attention by the courts. It was decided that the fence is intended to prevent the employee from coming into contact with the dangerous parts. It was not intended to protect from parts of the machine, which may be ejected (Selwyn, 1994: 161).

The effect of the Factories Act 1961 was insignificant in reducing machinery related accidents and ill health, due to the following reasons: -

1. The failure to impose effective duties on people who were best placed to engineer health and safety from the onset i.e. designers and manufacturers. The prescriptive legislation only considered a small number of hazards. For example, contact with set screws, bolt or keys, which could cause entanglement, etc.
2. The fact that all hazards were not clearly identified in order to evaluate risk.
3. The narrow perception of safeguards available i.e. 'fencing'/encasing appears as the only option.
4. Emphasis on physical safeguards i.e. only mechanical hazards warranted attention. No consideration was afforded to such things as electrical, or work activity hazards such as repetitive tasks.
5. The logic was based on the requirement to fence dangerous machines in cotton mills and the dangerous parts of steam engines.
6. Uncertainty as to whether a machine was in fact safe.

2.4.2 The Health and Safety at Work etc Act 1974

The introduction of The Health and Safety at Work etc Act 1974 (HSWA), not only places responsibility for ensuring the health and safety of employees, including machinery safety with the employer (section 2), it also places the responsibility of ensuring safety of articles for use at work, including machines, on the designer, manufacturer and supplier (section 6).

Section 6 (1) placed the following duties on designer, manufacturers and suppliers. "It shall be the duty of any person who designs, manufactures, imports or supplies any article for use at work to ensure, so far as is reasonably practicable, that the article is so designed… as to be safe… when properly used".

In essence section 6 only concentrated on protecting operating personnel during the normal use of the machinery. In addition it placed an obligation on the employer to ensure that the operating instructions were followed to the 'letter of the law' (HSWA 1974). At no time was any consideration given to human failing such as operator error.

The term "reasonably practicable" was intended to describe the balance between risks on the one hand, and cost, in order to achieve adequate levels of safety, on the other. It is understandable therefore that the lack of practical guidance in terms of whether a machine was in fact safe, could have been used as a get out clause by cost conscious designers.

The introduction of the Consumer Protection Act 1987 (Schedule 3), resulted in a change to section 6 of The Health and Safety at Work etc Act 1974. The revision became effective in 1988.

The revised section 6 continues to remain as a current legal requirement for machinery designers, manufactures and suppliers, in addition to the EU style legislation. Upon analysis of the changes it is possible to note that the term 'when properly used' has disappeared (HSWA 1974). Designers, manufacturers and suppliers were now required to define the intended use and identify foreseeable misuse.

One of the major benefits of revised section 6 was that it provided clearer guidance by considering the evaluation of risks. However, in practice, the revision has made very little difference due to a general lack of understanding shown on the part of machine designers, manufactures and suppliers. At no time was any practical guidance given by any Approved Code of Practice (ACoP), on how adequate levels of health and safety could be achieved, outside of the "physical" context (Raafat, 1996: 2).

The drawbacks associated with the above legislation highlights the need for a new approach to machinery safety. A proactive approach would aid in the consistency of resource allocation and the decision making process.

2.4.3 British Standard Code of Practice for Safety of Machinery (BS 5304)

The British Standard BS 5304 "Safety of machinery" 1988 introduced a classification of machinery hazards. These included: -

1. Entanglement - hair, clothing, gloves etc., could become entangled in rotating parts of machinery e.g. drilling machines etc.

2. Friction/abrasion - parts that were rough or abrasive, could injure as a result of touching e.g. abrasive wheels etc.
3. Cutting/severing - parts which are sharp e.g. blades etc.
4. Impact - parts, which as a result of their speed of movement could cause injury if someone was to come into contact.
5. Shearing - components whose movement creates a scissors action e.g. guillotines etc.
6. Crushing - where limbs etc., are trapped and subsequently crushed by closing or passing movement e.g. press etc.
7. Drawing-in - where limbs, hair, clothes etc., are drawn into a trap e.g. rotating rollers.
8. Stabbing/puncture - flying objects, needles etc., rapidly moving and puncturing the body.

Upon analysis of the above it is possible to note that BS 5304 only concerned itself with the potential for physical injuries. It failed to consider hazards such as electrical, ergonomic principles, high-pressure fluid injection, radiation, vibration etc. On the more positive side parts of BS 5304 was used as a basis for drafting the new European standard EN 292 (Nicholas, 2000a).

2.5 Compliance With Legislative Requirements

The limitations of the Health and Safety at Work etc Act 1974 (HSWA) have come into sharper focus in recent years, in particular, a series of major disasters and horrific individual deaths. For example the case of George Kenyon, who was killed when he was sucked into a plastic crushing machine. An investigation by the HSE revealed that the machine had been wired in a way that would allow it to operate with the interlocked guard open. This immobilised safety mechanism, enabling increased production throughput, provides a grisly reminder of the priorities assigned to production as opposed to health and safety (Health and Safety Information Bulletin, 1991).

The criticisms of the HSWA 1974 have focused on two issues. Firstly, there is the philosophy of self-regulation, which underpins the statute (Bach, 1994: 125). The self-regulation philosophy is based on two questionable assumptions. First, that managers and employees in general share the same beliefs in maintaining a safe workplace. Second, that apathy causes accidents.

The unitary view that management and workers share the same beliefs is not borne out in practice (Cullen, 1990, re-quoted Bach, 1994: 125). In their examination of accidents, Nichols and Armstrong (1973, re-quoted Bach, 1994: 125) demonstrated that many accidents were associated with the fault of the production process, and employees' attempts to keep up with production. They concluded that pressure to maintain production from managers anxious to meet targets led to unsafe working practices.

Dwyer's case studies (1983: 147-160) found that certain employees consented to dangerous working conditions in return for higher wages.

Robens attributed accidents to workers apathy and indifference to safety. This focus to blame the individual has been widely endorsed. However, it is necessary to place accidents in the social context in which they occur. Instead of focusing exclusively on individual attributes, the incentives within organisations that effect safety need to be considered (Bach, 1994: 126).

Lees (1980, re-quoted Cox and Tait 1991: 220) commented the unsafe acts could be due to violations as for example, a result of lack of understanding. He listed many learning points from the Flixborough disaster. These included the importance of understanding and managing the potential conflict of priorities between safety and production and the necessity for adequate design and testing, and correct use of standards.

In the absence of incentives within organisations, which emphasise health and safety there is a requirement to apply external forces, in the form of HSE enforcement of the legislation. This has clearly not been the case.

During the 1980s the number of small firms increased very dramatically (Bannock and Daly, 1990; 255-258). The HSE expressed concern about the adequacy of safety arrangements in small firms and increasing targeted literature and campaigns in this area. During 1990 the HSE swooped on 1614 small firms and as well as frequent breaches of the law they found that one-third of these small firms were not registered with the HSE (Financial Times, 10 October 1990).

The HSE, in accordance with its emphasis on self-regulation, has preferred to secure compliance with law through education and persuasion rather than through prosecution. This reluctance to prosecute has been reinforced by the inordinate amount of inspectors' time needed to bring and achieve a successful prosecution (Health and Safety Bulletin, 1991).

The HSE has also been reluctant to bring prosecutions because of the low level of fines metered out to offenders (Bach, 1994: 126).

2.6 Regulation By The European Union

At a time when the limitations of existing legislation were becoming apparent, initiatives to regulate all aspects of the work environment were emanating from the European Economic Community (EEC) in Brussels.

From 1 January 1973, the UK became a member of the EEC and by the European Communities Act 1972 all obligations arising out of the various treaties which set up the Community were given legal effect in this country (Selwyn, 1994: 11).

A Directive of 1983, 83/189/EEC, as amended recognises the value of standardisation and sets out the procedure for the provision of information in the field of technical regulations and standards. The aim was to achieve transparency and common purpose and ensure standardisation is tackled on a European-wide basis and is not a piecemeal nation-by-nation process (Selwyn, 1994: 325).

It is the duty of Member States of the European Union to enforce the legislation resulting from directives. Failure to do so can result in legal sanctions against the offending Member State.

The HSC noted in 1990 that the European Union has now to be regarded as the "principal engine" of health and safety law.

2.7 The Risk Based Approach To Machinery Safety

In May 1985, the EU Ministers agreed to a 'new approach to technical harmonisation' to enable free trade between EU partners (Raafat, 1996: 2). Product directives set out EHSRs, which must be met before specific safety-related products are placed on the market anywhere in the EU. Compliance with EHSRs can be shown by conformance with relevant technical standards. A key element of the 'new approach', therefore is the development of EN transposed harmonised standards - that is, standards that are identical in each EU member state save for the language that they are written in. The standards are determined at European level and then adopted by each of the national standards bodies, which in the UK is the British Standards Institute (BSI).

The European Economic Area (EEA) is made up of two distinct trading areas. These are: -

1. The European Union (EU) (formally known as the European Economic Community (EEC) and later the European Community (EC)). References in current documents still refer to EEC and EC.
2. The European Free Trade Area (EFTA) is mostly concerned with trading between member states.

In 1992 the EEA was created when the EU and EFTA signed a treaty to remove trade barriers between them and promote the free movement of goods, persons, services and capital. Consequently, the EU council directives that relate to trade are now used by EFTA.

The member countries of the EU are: -

Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom.

The members of EFTA are: -

Iceland, Liechtenstein and Norway.

Switzerland is not a member of the EEA but does participate in the standards process.

The Machinery Directive 89/332/EEC as amended is aimed at machinery suppliers and was implemented in the UK by the Supply Of Machinery (Safety) Regulations 1992 (SMSR), which came into force on 1 January 1993. There was a transition period up to 31 December 1994 before all aspects of the legislation came into force. During this transition period supplied machinery had to comply fully with existing legislative requirements and standards in the UK. A supplier who affixes the CE mark to a product is claiming compliance with all relevant directives.

In place of reactive and prescriptive legislation and standards mainly directed at users, the 'new approach' represented a remarkable break through in the risk-based approach to machinery safety. The crucial role of risk assessment affects both machinery suppliers and end users. The European harmonised standard EN 292 'Safety of machinery: basic concepts, principles for design' outlines the role of risk assessment for designers to identify intended use and foreseeable misuse throughout the life cycle of machinery, as required by the Machinery Directive. Risks should be reduced, as far as possible, by design. Employers (users), on the other hand, need to comply with the requirements of regulation 3 (1) of the Management of

Health and Safety Regulations 1999 (MHSWR) by carrying out 'suitable and sufficient' risk assessment on all work equipment and activities.

In addition, the user must ensure compliance with the requirements of the Provision and Use of Work Equipment Regulations 1992 (PUWER) and revoked by the Provision and Use of Work Equipment Regulations 1998 (PUWER 2). An explanation of the key requirements of PUWER 1992 and 1998 will follow later in this Chapter.

There is a shared emphasis on the importance of audit systems. EU regulation(s), with their stress on the importance of risk assessment, have encouraged the growing use of systems designed to identify, eliminate and reduce work-based hazards (Bach, 1994: 143). Environmental audits take this process further by examining the environmental impact of the firm's activities and proceeding to make recommendations on how to alter company practice to improve the environment and reduce expenditure. British Airways has examined the impact of its operations at Heathrow Airport, detailing noise levels, fuel consumption and emissions (Jack, 1992).

Risk assessment is of fundamental importance to all regulation(s) enacted in response to EU directives, due to the fact that the level of risk identified determines a series of priorities, which include for example, the selection of the most appropriate safety/control measure to deal with the hazard, and what standard of safeguard, protection device and safe system of work are required. Risk assessment can highlight systematically how hazards can occur and provide a clearer understanding of their nature and possible consequences (Raafat, 1996: 30).

Assessment techniques range from simple qualitative approaches of hazard identification, through too more sophisticated quantitative methods of risk assessment where numerical values for frequency or probability are determined.

The new EU standards are risk-based approach, by virtue of the fact that they are considered to be relevant within the scope of the machinery under investigation. In addition each EHSR, will include an explicit safety aim and assess whether the risk has been reduced to a predetermined level. The EHSRs will be explained fully in Chapter 3.

Hazard analysis is considered to be an essential ingredient to the overall risk assessment framework. If anything other than a structured and systematic approach were utilised at this stage, it would mean hazards/hazardous situations would be overlooked, which could result in serious consequences to organisations and more importantly to operating and maintenance personnel.

Raafat (1996: 33) defines a hazard as some thing with 'the potential to cause injury or damage to health'.

The risk assessment procedure contains two essential elements. These are: -

1. Risk Analysis - where hazards/hazardous situations are systematically identified and where by their consequences are analysed. The level of risk being estimated or measured.
2. Risk Evaluation - within this element a judgment is made as to whether or not a risk is acceptable/tolerable, and corrective/preventative actions are considered as viable solutions in order to reduce the risk to a practicable level.

It is important in this respect to distinguish between continuing hazards, (those inherent in the work activity/machinery under normal conditions), and those hazards which can result from failures/errors, (e.g. hardware/software failures as well as foreseeable human error). This is referred to in EN 292 as a 'hazardous situation'.

For new machinery, suppliers need to demonstrate through risk assessment that the machine is safe by design, while users need to ensure that residual risks from the machine, and any additional risks created by its introduction into the workplace, are appropriately controlled. Suppliers of new machines are required to inform the users of residual risks and of a means by which they might be controlled - for instance, by procedures or training.

2.7.1 The Supply Of Machinery (Safety) Regulations 1992

A summary of the main requirements of The Supply Of Machinery (Safety) Regulations 1992 (as amended) is as follows: -

1. Regulations 3-10

Machinery is defined as an assembly of linked parts or components, at least one of which moves, with appropriate actuators, control and power circuits, etc. joined together for a specific application, in particular for processing, treatment, moving or packaging of material (regulation 4). The definition includes an assembly of machines which functions as an integral whole as well as interchangeable machinery; (not spare part or tool) which can be assembled with the machine by the operator; for instance, an item of agricultural equipment to be attached to a tractor.

Schedule 5 of the Regulations contains a list of excluded machinery such as those, for example, requiring only manual effort. Machinery exported outside of the European Union as well as those items covered by other EU directives are also excluded.

2. Regulations 11-25

The Regulations make it an offence (Regulations 11 and 12) for a person to supply relevant machinery within the EU where: -

1. The machinery does not satisfy the requirements of the EHSRs, which are contained in Schedule 3 of the Regulations.
2. A technical file has not been constructed.
3. An appropriate conformity assessment procedure has not been carried out.
4. The requirements of other directives have not been met.
5. An appropriate EU declaration of conformity/incorporation has not been issued.
6. The CE mark has not been properly affixed, in the case of machinery where a declaration of conformity has been issued.
7. The machine is not safe.

All of the above requirements will be examined in detail in Chapter 3

The procedure for showing that the relevant machinery conforms to the above requirements involves the preparation of a technical file (regulation 13,14 and 15). This must include technical drawings, test results, a list of the appropriate EHSRs, the transposed harmonised standards utilised, other relevant standards, technical specifications, a description of the methods adopted to eliminate, reduce, control hazards, a copy of relevant instructions for operators/maintenance etc. For machinery posing special hazards (listed in Schedule 4 of the Regulations) further action is required which involves submitting the technical file to an approved body (regulation 17,18 and 19). If requested, the approved body will consider whether the transposed harmonised standards have been correctly applied. If this is the case, then a certificate of adequacy will be issued (regulation 20).

Alternatively an EC type-examination (regulation 21) of the machine can be undertaken by the approved body in order to demonstrate that it satisfies the relevant provisions of the EU Machinery Directive. An EC type-examination certificate will be issued, if in the opinion of the approved body, the machine satisfies the relevant EHSRs that apply to it. Once again all of these terms and requirements will be explained in more detail in Chapter 3.

The EHSRs relating to the design and construction of machinery, contained in Schedule 3 to the Regulations, cover in some detail matters relating to controls, protection against mechanical hazards, characteristics of guards and protection devices, protection against other hazards, maintenance and indicators (information and warning devices, markings and instructions). Additional requirements relate to agri-foodstuffs, portable, woodworking, mobile, lifting and underground machinery.

A EU declaration of conformity/incorporation must be drawn up which states that the relevant machinery complies with all the EHSRs that apply to it (regulation 22 and 23). Such a declaration must include a description of the machinery (make, type, serial number), indicating all the relevant provisions with which the machinery complies: give details of any certificate of adequacy/EC type-examination certificate, and specify relevant transposed harmonised standards utilised etc.

All documentation relating to the particular machinery must be retained for ten years after production of the last unit of that machinery (regulation 24).

The CE mark is regarded as properly affixed only if: -

1. A EU declaration of conformity has been issued.
2. It is affixed in a distinct, visible, legible and indelible manner.
3. The machinery complies with other directives.

It is an offence to affix a CE mark to a machine, which does not satisfy the EHSRs, or to machinery that is in fact not safe (regulation 29). The definition of the meaning of 'safe' will be discussed in detail in Chapter 3.

The Machinery Directive 89/392/EEC, has to date been subjected to four amendments and has therefore resulted in changes to aspects of the SMSR. The amendments to the Directive are as follows: -

1. Amendment 91/368/EEC - this amendment added mobile machinery and mobile lifting equipment.
2. Amendment 93/44/EEC - this introduced the requirements relating to machinery concerned with 'hazards due to the lifting or moving of persons'.

3. Amendment 93/68/EEC - this removed the requirement to add the year of assessment to the CE mark and recognised the enlargement of the scope of the Directive to include the EFTA members in the EEA.
4. Amendment 93/465/EEC - this document details the requirements of notified bodies for establishing conformity including quality control audit requirements.

As a result of a further need to simplify the Directive and address existing practical and interpretational problems, the EU proposed a fifth amendment in July 1997. The existing draft makes several proposals such as amending the EHSRs to provide better logic to their presentation and to reduce some duplication. The objective of this is to re-emphasise the need that machinery designers and manufacturers to consider the EHSRs in their entirety as a basis for undertaking a comprehensive risk assessment. In addition there is a proposal to bring partly completed machinery ('quasi machinery') into the scope of the Directive.

There is also a proposal to change the conformity assessment arrangements under Annex IV of the Directive (Schedule 4 SMSR). As noted earlier in this Chapter, only certain (special hazard) machinery listed in Annex IV, e.g. presses, injection/compression moulding machines and circular/portable chain saws, require third party type examination. At present, suppliers of such products must demonstrate that they comply with relevant EN standards where they exist; otherwise they must submit them for notified body approval. The EU propose that, where the supplier wishes to rely on the European standards route to demonstrate compliance with EHSRs, a third party, usually an approved body, must check the technical documentation to ensure that the standards have been correctly applied.

The UK has opposed this proposal (Bullock, 2000), based on the belief that there is no hard evidence to suggest that machines that have been type examined have achieved greater compliance with the requirements of the Directive than those built to harmonised standards. It will be interesting to determine, whether this belief is confirmed by the empirical research findings.

2.7.2 The Provision and Use of Work Equipment Regulations 1992

The Use of Work Equipment Directive (UWED) 89/655/EEC was implemented in the UK as PUWER. Clearly the key emphasis of the research was to examine the degree of compliance with the EU Machinery Directive. However, there is a very important relationship between the SMSR and PUWER, in particular where the machinery supplied to an employer is not safe. This in effect could leave the end user open to prosecution under PUWER. Therefore the debate will consider this inter-relationship between the two pieces of machinery legislation.

Regulations 1-10 of PUWER applied to existing items of machinery. However regulations 11-24 which covered the 'hardware items did not come into force until 1 January 1997. PUWER has now revoked sections 12-16 (dangerous parts of machinery, fencing and construction and maintenance of fencing) of the Factories Act 1961.

Machines complying with regulations made under the EU Machinery Directive will be exempt from any corresponding requirements in regulations 11-24 of PUWER, simply because, by definition they should already meet those requirements.

Some of the key regulations of PUWER, which have a forbearing on supplied machinery, are: -

1. Work equipment must be suitable for its intended use (regulation 5).
2. Conformity with community requirements (regulation 10). Machinery provided after 31 December 1992 must conform to relevant legislation, which implements EU directive(s).
3. Dangerous parts of the machinery (regulation 11). Employers must take measures to prevent access to any dangerous parts of the machinery. The hierarchy of measures includes: -
    - A. Fixed enclosed guarding.
    - B. The provision of other guards or protective measures e.g. interlocked guards.
    - C. The provisions of jigs, holders, push sticks or similar protection appliances.
    - D. The provision of information, instruction, training and supervision.

4. Protection against specified hazards (regulation 12). "Every employer shall take measures to ensure that exposure of a person using machinery, to any risk to his health or safety from any specified hazard, such as falling or ejected articles or substances, rupture or disintegration of component parts, catching fire or overheating, and unintended or premature discharges or explosions".

5. Controls and control systems (regulation 14-18). Work equipment should be provided with: -

    A. One or more controls for starting the equipment or for controlling the operating conditions (speed, pressure etc.) where the risks after the change is greater than or have a different nature from the risks beforehand.

    B. One or more readily accessible stop controls that will bring the equipment to a safe condition in a safe manner and which operate in priority to any control that starts or changes the operating conditions of the equipment.

    C. One or more readily accessible emergency stop controls - unless by the nature of the hazard, or by the adequacy of the normal stop controls (2. above), this is unnecessary. Emergency stop controls must operate in priority to all other controls.

D. Controls, which are clearly visible and identifiable (including appropriate marking). In addition, the position of the controls should be such that the operator can establish that no person is in danger as a result of the operation of the controls or, where this is not possible, safe systems of work should be established to ensure that no person is in danger as a result of the equipment starting. Where this is not possible, there should be audible, visible or other suitable warning whenever the work equipment is about to start. Sufficient time and means shall be given to a person to avoid any risks due to the starting or stopping of the work equipment.

E. Control systems should not create any increased risk. Faults or damage in the control system or losses of energy supply should not result in additional or increased risk and should not impede the operation of ant stop or emergency stop control.

Upon analysis of the requirements listed in PUWER, it is disappointing to note that the contents tend not to follow a risk-based approach. Therefore they are not compatible with the ultimate goal of the Harmonised requirements. For example regulation 11 sets out a hierarchy of measures in relation to dangerous parts of a machine, with fixed guarding at the top of this list of priorities. Fixed guards are not a viable alternative, particularly when frequent access is required to the machine parts. Operator and maintenance personnel have an ongoing tendency to 'leave off ' fixed guards.

With hindsight the people responsible for commenting on the nature and structure of the regulations would have been better advised to have adopted a risk based approach, or to have at least provided guidance on this link to ensure overall legislative compatibility.

In addition we can determine that the contents of PUWER already existed previously in one form or another, or at the very least constitute what can only be described as accepted best practice. For example, section 14 of the Factories Act 1961 (now revoked) stated, "Every dangerous part of any machinery... shall be securely fenced". PUWER calls for fixed guarding measures to control 'dangerous parts of machinery' (regulation 11).

The criticisms noted above have recently been borne out in practice as a result of a test case in 1996 brought to court, by the Health and Safety Executive (HSE). An employee within a large printing company was seriously injured when their "left arm was caught between the stacker closing pneumatic guide bars" (Raafat, 1999). The HSE concluded that the machinery did not fulfill the requirements of regulation 12 of the SMSR, in that it did not satisfy the relevant EHSRs and that the design did not comply with the requirements of the applicable EN standards. It is understood that the supplier was found guilty (Raafat, 1999).

In a surprise move by the HSE, legal proceedings were initiated against the user for non-compliance with regulation 10 (1) of PUWER. This places an absolute duty on a user to ensure that machinery complies with all relevant EU Directives.

These legal proceedings were utilised as a test case by the HSE and tried in a Crown Court. The outcome was that the judge decided that regulation 10 (1) was inadequate and unenforceable, largely due to the phrase 'shall ensure'. This, in his view, was open ended and could be interpreted that the duty required the user to dismantle the machine to ensure that it complied with all relevant provisions. This was clearly absurd.

The HSE amended the indictment to a charge under regulation 11 (1), the requirement to prevent access to any 'dangerous part of the machine'. The user was ultimately found guilty, (Raafat, 1999). The user of the equipment could have equally been found guilty under the Factories Act 1961 section 14, before it was revoked, so in reality PUWER 1992 has achieved very little in practice.

2.7.3 The Provision and Use of Work Equipment Regulations 1998

The Provision and Use of work Equipment Regulations 1998 (PUWER '98) came into force on 5th December 1998. PUWER '98 brings into effect the non-lifting aspects of the Amending Directive to the Use of Work Equipment Directive (AUWED) 95/63/EC (Raafat 1999). Its primary objective is to ensure that work equipment should not result in health and safety risks, regardless of age, condition or origin. PUWER '98 replaces PUWER '92.

The new requirements under AUWED relate to mobile work equipment, lifting equipment and the inspection of work equipment.

The lifting requirements have been implemented through the Lifting Operations and Lifting Equipment Regulations (HSC, 1998a).

An attempt is made under PUWER '98, Approved Code of Practice (ACoP) and Guidance, to link risk assessment with MHSWR. As a general risk assessment is required under regulation 3 of MHSWR, no specific regulation requiring a risk assessment to be under taken is set out in PUWER '98 (HSC, 1998b).

PUWER '98 ACoP and Guidance recommends the use of the HSE's guidance booklet: five steps to risk assessment (revised 1998c).

In no way can the five steps to risk assessment be regarded as a 'suitable and sufficient' approach in the case of complex machinery. A more in depth analysis utilising a 'task based' approach is required. Upon analysis of the risk assessment booklet it is possible to conclude that the approach outlined is far too generic and superficial to be adequately applied to machinery. The conclusions are based on the following: -

1. Hazards are described in general terms. For example those caused by mechanical equipment, which is classified as grinding equipment, chain saws, stretch wrap machines etc. This does not identify the type of hazards involved (e.g. crushing, cutting/severing, abrasion, impact etc.) and how these can cause injury or ill health.
2. The definition of risk does not include consequences.
3. No attempt is made to analyse consequences (severity of injury/ill health). This is a vital ingredient in measuring risk.
4. It does not demonstrate how risks are evaluated in a structured and systematic manner.
5. The objective of the risk assessment appears to be to identify existing measures to control identified hazards.

The main changes in PUWER'98 include the following: -

1. Inspection requirements are incorporated into both PUWER (regulation 6) and LOLER.
2. The definition of work equipment to include installations.
3. Guidance about regulation 7 (specific risks).
4. Changes to regulation 10 (conformity with community requirements).
5. Changes to regulation 18 (control systems).
6. New regulations to replace the old Power Press Regulations of 1965 and 1972.

The requirements for dealing with specific risks (regulation 7) have not changed under PUWER '98. The guidance of PUWER '92 did not define what specific risks are, nor did it require additional measures. The ACoP and Guidance to PUWER '98 on the other hand makes several conflicting and confusing statements. No attempt is made to define what is meant by specific risks or what makes such risks 'specific' (Raafat 1999). The examples given in the ACoP and Guidance, relates to risks from a platen, printing machine or from drop forging, (Raafat 1999).

No explanation is given on what are the specific risks associated with these machines. Hazards associated with a drop forge may include noise, vibration, crushing, impact, hot molten metal splashes etc. Are these what is meant by specific risks?

Regulation 10 of PUWER '98 (conformity with community requirements) was not subject to AUWED, but was revised in the light of the enforcement difficulties, discussed earlier in PUWER '92.

In a consultative document, HSC proposals for amending regulation 10 included an addition which would allow a defence of having taken 'all reasonable precautions and exercised all due diligence' under the regulations.

PUWER '98 and its ACoP and Guidance did not include the above defence. Regulation 10 requires that 'every employer shall ensure (absolute duty) that an item of work equipment has been designed and constructed in compliance with any essential requirements under relevant directives (HSC, 1998b).

The defence offered by the guidance to regulation 10 includes the following: -

1. A check by the employer to see that the CE Mark is affixed and ask for a declaration certificate.
2. The adequacy of operating instructions and information on residual risks.
3. The employer should check the equipment for obvious faults.

As a result of the conclusions drawn by this research (Chapter 4 and 5), it is anticipated that regulation 10 will in the future be open to legal interpretation and argument.

The HSE have produced two booklets, 'Buying New Machinery' and 'Supplying New Machinery' HSE, 1998a and 1998b). Upon analysis it is possible to conclude that both booklets are somewhat superficial and are over simplified. The booklets do not contain basic requirements such as a format for declaration certificates and the structure of relevant EN machinery safety standards etc. In addition the booklets make no reference to risk assessment.

PUWER '98 has missed an opportunity to combat the criticisms of regulation 10.

Analysis of five prosecution notices served since 1996 reveals that non-compliance with Regulation 11 of PUWER' 92 is the most frequently cited breach (Raafat 1999). The wording of regulation 11 of PUWER '98 is exactly the same as PUWER '92. An attempt was made in PUWER '98 ACOP and Guidance, to link risk assessment with regulation 11.

The analysis of PUWER '98 has shown that regulation 11 continues to lack a risk-based approach to machinery safety and is therefore no improvement over The Factories Act 1961 (now revoked).

The minor changes to regulation 18 (control systems) indicates a requirement to ensure that allowances are made for 'the failures, faults and constraints' to be expected. However, no practical examples exist on a technique, such as Failure Modes Effect Analysis (FMEA), which would be beneficial to anyone identifying failure, faults and constraint situations.

The analysis has shown that PUWER '98 has missed an opportunity to ensure its compatibility with the risk-based approach, as set out by the SMSR.

2.8 The Transposed Harmonised EN Standards

Transposed EN standards originate from European standards produced by the appropriate European Standards Body. This is either the European Committee for Standardisation (CEN) or the European Committee for Electrotechnical Standardisation (CENELEC). These bodies produce draft standards, which are distributed to each member state for comment. The designated number of the relevant standard is indicated with a pr EN prefix, in order to indicate provisional status. When a standard is adopted, through a process of majority voting, it loses its pr status and is indicated with an EN prefix e.g. EN 953. All of these standards are published in the official journal of the 'European Committee' (Nicholas, 2000a).

Each standard is then adopted or transposed by the standards body of each member state. Within the UK British Standards Institute (BSI) undertakes this. It is the transposed version of the European standard in the member state that should be referenced in the design and construction of the machinery. The transposed version within the UK is indicated with a British Standard BS EN prefix e.g. BS EN 953. Even though a standard is in provisional format, it should be referenced during the design and construction process due to the fact it represents 'state of the art' at that particular point in time (Nicholas, 2000a).

Application of the European transposed harmonised machinery safety standards is fundamental to the risk-based approach (Raafat, 1996). These Standards have now replaced all British standards relating to machinery safety, as well as the national standards of other EU member states.

The International Organisation For Standardisation (ISO) and International Electrotechnical Commission (IEC) (ISO/IEC 1998) are currently undertaking a process of incorporating the European machinery safety standards into international standards. The American National Standards Institute (ANSI) is also considering the EU risk-based approach to machinery safety (ANSI 1998).

2.8.1 The Status And Scope Of The Harmonised Standards

The role and status of the harmonised European standards has been widely misunderstood, due mainly to the previously prescriptive nature of health and safety legislation and standards. The 'new approach' is based on the legal status of the EHSRs as an objective to be achieved, with the harmonised standards representing state of the art means of meeting the requirements. The harmonised standards do not have the same legal status but do reflect recognised good practice and should therefore be given primary consideration (Nicholas, 2000a).

Makin (1989) clarified the role of the harmonised standard in relation to the EHSRs: 'EHSRs are expressed in general terms and it is intended that the European harmonised standards should fill in the detail so that designers have a clear guidance on how to achieve conformity with the Directive'.

The harmonised standards therefore provide guidance on the currently recognised methods of achieving compliance with the EHSR. Their legal status is similar to that of an Approved Code of Practice and was summarised by Van Gheluwe (1989) of the European Commission as follows: 'The standard, whether harmonised or not, is never mandatory in the context of the Directive. A manufacturer may decide not to apply it and to adopt other solutions'. However, compliance with relevant standards drawn up by CEN, or its electrical counterpart, CENLEC, is probably the most effective means of demonstrating that EHSRs have been met. The alternative would be the application of a robust risk assessment that considers, from first principles, all relevant hazards and hazardous situations, and their control.

2.8.2 Structure Of The Harmonised Standards

Each standard starts by listing the machine or process hazards that are considered relevant within its scope and use. In addition, each health and safety requirement should include an explicit safety aim to assess whether a risk has been reduced to an acceptable level.

An overview of the structure for the standards is shown in Figure 2.2. The standards are categorised into three main types (Nicholas, 2000a).

Type A standards provide general requirements applicable to all machines. The primary standard relating to the Machinery Directive is EN 292, which comprises two

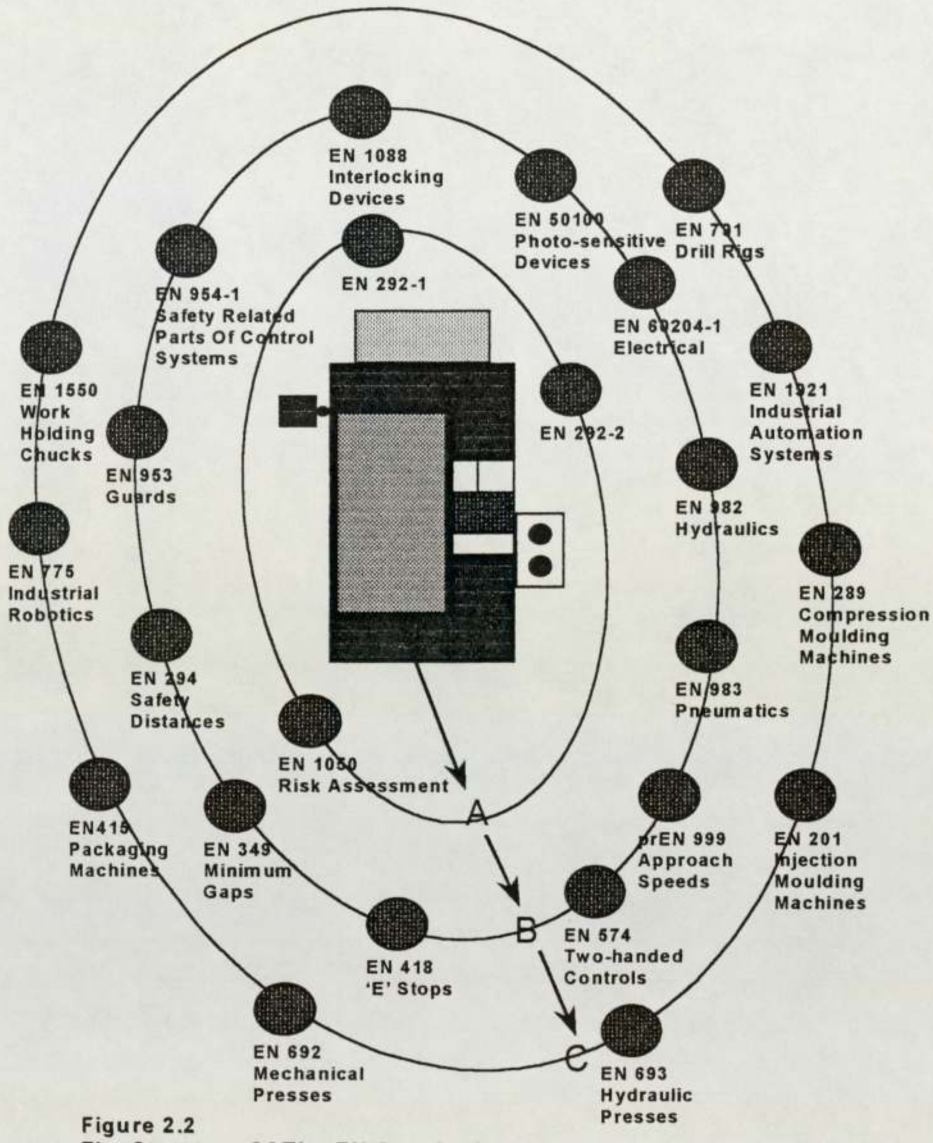


Figure 2.2
The Structure Of The EN Standards

parts: part 1 'Basic terminology, methodology'; and part 2 'Technical principles and specifications'.

EN 1050 'Safety of machinery: Principles for risk assessment' is also regarded as a type A standard. It provides a framework for risk assessment and the range of hazards to be considered in the assessment.

There is no standard risk assessment technique, since this will depend on the nature of the machinery hazards and the degree of interactions with humans. Any risk assessment, however, should be both suitable and sufficient and therefore the degree of detail and techniques used, are a function of the risk level and the complexity of the situation under study (Nicholas, 2000a).

Type B standards relate to techniques, principles or components, which are applicable to a range of machines. B1 standards provide generic guidance and information. For example EN 294:1992 'Safety distance to prevent danger zones being reached by the upper limbs'. B2 standards outline generic safety standards for hardware. For example EN 418:1992 'Emergency stop equipment - Functional aspects - Principles for design'. Type B standards may be regarded as 'horizontal' standards dealing with single issues relating to machine safety (Nicholas, 2000a).

Type C standards cover particular types or classes of machine. For example BS EN 201:1997 'Rubber and plastics machines - Injection moulding machines - Safety requirements'. Type C standards, more of which have yet to be produced with others in provisional format, may be classed as 'vertical' standards. In following a particular C standard, extensive cross-referencing to relevant sections of A and B standards is needed (Nicholas, 2000a).

2.9 DTI Study On Impact Of EU Machinery Directive

In 1993 the DTI commissioned a research organisation to conduct a telephone survey with 600 UK powered machinery exporters. The focus of this study was to assess the effects on industrial sectors, the impact on non-tariff barriers to trade, and the costs of compliance with the new set of regulations and standards (DTI, 1998).

In order to assess 'changing attitudes', and to analyse the full impact of the EU Machinery Directive a follow up survey was undertaken in 1998.

The key conclusions reached by the DTI study are as follows: -

1. Some 62 per cent of respondents believed that compliance costs of the Directive are higher than previous compliance costs with national requirements. In 1993 the average initial and annual compliance costs for national requirements were estimated to be approximately £10,000 and £6,500 respectively. This compares with an average initial compliance cost for the Directive of approximately £25,000 and annual costs of £16,000.
2. Almost 99 per cent of respondents were aware of the Directive. This compared with only 69 per cent in 1993.
3. Over 90 per cent of organisations comply with the Directive and over 58 per cent feel that they fully comply.

4. Respondents were asked to identify the main provisions of the Directive. It was concluded that health and safety aspects (EHSRs) were cited on 48 per cent of occasions, over a fifth mentioned CE marking and the requirement to compile technical files and to undergo type examinations received the least mention - just 7 per cent and 6 per cent respectively.

It will be interesting to determine how these findings compare with the findings of this research, which are contained in Chapter 4 and Chapter 5.

This Chapter has reviewed the development of legislative compliance and standards within the UK. It has paid particular attention to the role of the EU, which has emerged as the principal player in the development of improved health and safety performance. A key requirement of the EU approach is the shared emphasis of risk assessment, the requirement for which is contained within various directives. This is clearly a more proactive beneficial remedy as opposed to remedies, which emerge and are considered in the aftermath of accidents.

In addition, the Chapter examined what models were available to designers, which would aid them in integrating health and safety in machinery design. It concluded that there is no universally accepted approach. Chapter 7 will attempt to resolve this problem.

The thesis will now move on to consider the route to demonstrating compliance with the EU Machinery Directive.

Chapter 3: The Route To Demonstrating Compliance With The EU Machinery Directive

This Chapter examines the root to demonstrating compliance with the EU Machinery Directive and SMSR. It discusses in detail all of the points highlighted in the previous Chapter and places them in a logical order.

Machinery suppliers need to demonstrate that a machine is in fact safe through a framework set out in the Machinery Directive and SMSR. Despite the requirements of section 6 of the Health and Safety at Work etc Act 1974, suppliers traditionally have gone through such a process only after an accident or as a result of legal action.

The main elements in the framework for demonstrating compliance are described below and summarised in Figure 3.1.

1. That a machine satisfies the EHSRs.
2. That a technical file be constructed and be readily assembled.
3. That a conformity assessment procedure is carried out on the machine.
4. That the requirements of other EU directives are met.
5. That a declaration of conformity or declaration of incorporation be issued at the supply stage.
6. That a 'CE' mark is affixed to the machinery where a declaration of conformity has been issued.

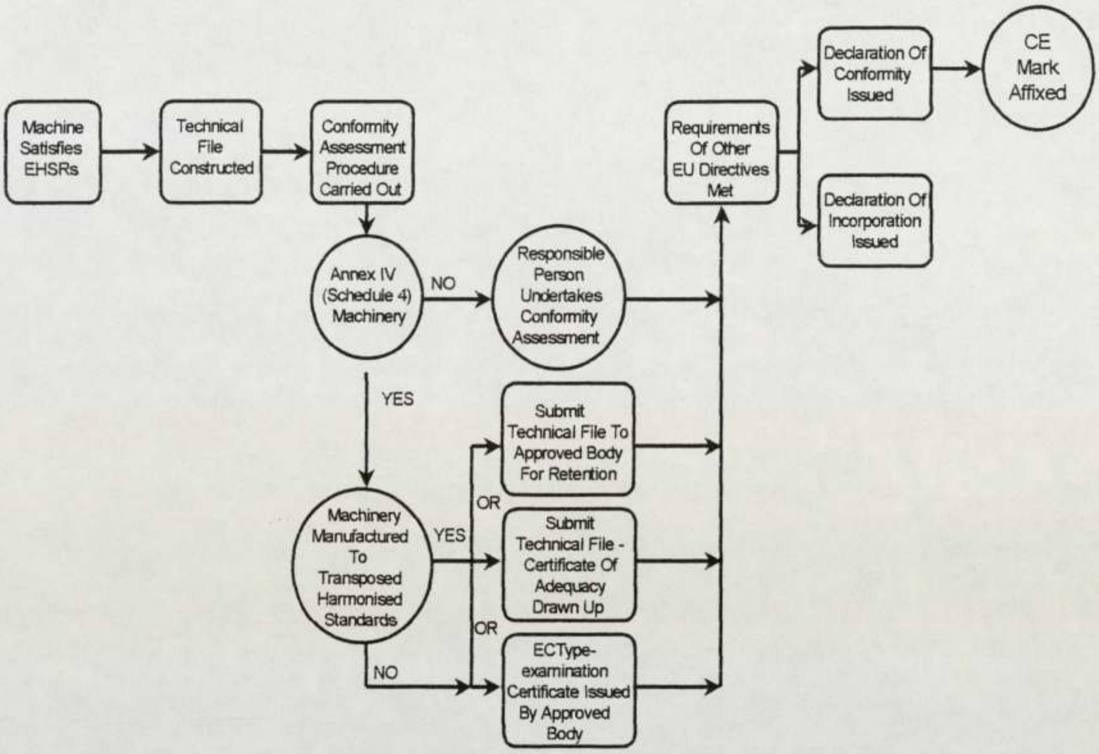


Figure 3.1 Route To Demonstrating Compliance With EU Machinery Directive

The Chapter will now consider each of these requirements in turn.

3.1 Machine Satisfies Essential Health And Safety Requirements (EHSRs)

The EHSRs are set out in Annex I of the EU Machinery Directive and Schedule 3 of the SMSR. There are twenty-two pages of numbered EHSRs, these are categorised in Table 3.1.

Table 3.1 Categories Of EHSRs

Section 1 - General machinery.
Section 2 - Agri-foodstuffs machinery e.g. machinery intended for the preparation and processing of food. This includes cooking, refrigeration, thawing, washing, handling, packing etc.
Section 3 - Hazards due to the mobility of machinery e.g. self-propelled, pushed, towed etc.
Section 4 - Hazards created by lifting operations e.g. load falls, overturning, collapse, tipping etc.
Section 5 – Machinery intended for underground use.

The EHSRs consider the different hazards/hazardous situations of the machine and require the designer/manufacturer to ensure that the specific requirements of each are met in full. They are couched in the term 'objects to be achieved'. The designer/manufacturer must consider each of the hazards in turn and decide how to construct the machine in order to eliminate these hazards at source or reduce them to a tolerable level. Table 3.2 provides a list of EHSRs for general machinery by way of example.

Table 3.2 EHSRs For General Machinery

General remarks – to include principles of safety integration, materials and products, lighting and the design of the machine to facilitate handling.
Controls – to include safety and reliability, control devices, starting/stopping, emergency stopping etc.
Protection against mechanical hazards – to include stability, risk of break up/disintegration, rotational speed of tools, prevention of risks relating to moving parts, choice of protection etc.
Required characteristics of guards and protection devices - to include fixed guards, movable guards etc.
Protection against other hazards – electricity supply, static electricity, other energy sources, errors of fitting, extreme temperatures, fire, explosion, noise etc.
Maintenance – Access to operating and service points, isolation, operator intervention, cleaning of parts etc.
Indicators – information devices, warnings, warnings of residual risks, marking, instructions etc.

The Chapter will now analyse some of the key EHSRs indicated.

3.1.1 Principles Of Safety Integration (EHSR No.1.1.2)

Machinery must be so constructed that it is fitted for its function and can be adjusted and maintained without putting persons at risk. The intended function of the machine must be clearly defined. The aim is to eliminate any risk of accident throughout the foreseeable lifetime of the machine. This will include design conception through to decommissioning and disposal, and will require a structured and systematic risk assessment to be undertaken.

In selecting the most appropriate methods, the manufacturer must apply the following principles, in the given order. These include: -

1. Eliminate and/or reduce risks as far as possible (safety through design/construction).
2. Take the necessary protection measures in relation to risks that cannot be eliminated (safeguards).
3. Inform user of residual risks (signs, procedures, instructions, training and personal protective equipment). Manufacturers must not only consider normal use but foreseeable misuse (Nicholas, 2000b).

3.1.2 Controls – Safety And Reliability Of Control Systems (EHSR No. 1.2.1)

Control systems must be designed and constructed so that they are safe and reliable, in a way that will prevent a dangerous situation arising. They must be able to with stand the rigours of normal use and external factors. In addition errors in logic must not lead to a dangerous situation.

3.1.3 Required Characteristics Of Guards And Protection Devices (EHSR No. 1.4.1)

Guards and protection devices must: -

1. Be of robust construction: strength, stiffness, durability etc.
2. Not give rise to any additional hazards.
3. Not be easy to bypass or render non-operational.
4. Be located at adequate distance from the danger zone.
5. Cause minimum obstruction of view.
6. Allow for essential work to be undertaken without the removal of the safeguard/safety device (Nicholas, 2000b).

The above analysis, an example of some of the EHSRs, has shown that they are worded in general terms as opposed to qualified specific objectives. The proposed amendment to the EU Machinery Directive discussed in the previous Chapter, mentioned the need to provide better logic to their presentation.

In reality the wording of the EHSRs does not demonstrate how their intended outcomes can be achieved in practice. For example what is an adequate distance in relation to the fitment of a guard? EN 294 and EN 349 provides the answer to this question. However, as we have already noted the use of the transposed machinery safety standards is a matter of their choice.

In addition it is possible to note that there is a certain amount of duplication within the various sections. For example control devices are mentioned in section 1, section 3, section 4 and section 5. Surely there is no need for this amount of duplication.

3.2 The Technical File

The conformity assessment procedure requires the manufacturer to assemble technical records, which describe the approach used to ensure that the machinery satisfies the EHSRs. These records are referred to as the 'technical file. The file must be kept for a minimum of ten years after production of the last unit of machinery has ceased (Raafat and Nicholas 1999).

The contents of the Technical File would include the following: -

1. The intended uses of the machine, clearly defined.
2. The risk assessment (if applicable).
3. Principles of safety integration. For example, how hazards have been eliminated/reduced/controlled etc.
4. A list of the EHSRs applicable.
5. A list of the transposed EN standards applicable.
6. A list of other standards applicable.

7. Technical specifications.
8. Test results (noise test report etc.).
9. Drawings to include: -
   A. Overall drawings.
   B. Control circuits etc.
10. Copies of instructions for safe operation, cleaning, maintenance, faultfinding, setting etc.
11. Warnings of residual risks.
12. Certificate of adequacy/EC type-examination test certificate where applicable.

3.3 Conformity Assessment Procedure

The responsibility for demonstrating that the machinery satisfies the EHSRs rests with the 'responsible person' (the manufacturer, his authorised representative in the EU or the importer of the machinery manufactured outside of the EU).

The Machinery Directive sets out various ways in which a supplier can demonstrate compliance with the EHSRs. This is known as the 'conformity assessment procedure'. There are three different conformity assessment procedures. These relate respectively to: -

1. Machinery other than that listed in Schedule 4 of the SMSR (Annex IV of the Directive).
2. Schedule 4 (Annex IV) machinery manufactured in accordance with the EU transposed harmonised standards.

3. Schedule 4 (Annex IV) machinery not manufactured in accordance with the EU harmonised standards or, where they do not exist (Raafat and Nicholas 1999).

Schedule 4 of the SMSR list categories of machines that pose special risks, including most woodworking machines, presses, press brakes, and injection and compression plastics-moulding machines.

For machinery not listed in Schedule 4, the supplier is required to issue a declaration of conformity or of incorporation, (see over), if satisfied that the machinery meets the EHSRs. The declaration (with, where appropriate, the CE marking to show that one had been issued) allows the machinery free movement within the EU.

Machinery which is categorised in Schedule 4 and manufactured in accordance with the transposed harmonised standards the responsible person must at their election: -

1. Draw up and forward to an approved body for retention by that body a technical file. Or;
2. Submit the technical file to the approved body requesting verification that the transposed harmonised standards have been correctly applied. If the approved body is satisfied that the transposed harmonised standards have been applied correctly, it may draw up a 'certificate of adequacy'. Or;

3. Alternatively the supplier can submit the technical file, and an example of the machine, to an approved body in order that they can undertake an EC type-examination of the machine. If the approved body is satisfied that the machine has been manufactured in accordance with the technical file, that it can be safely used under its intended working conditions, that all standards have been correctly applied and that it complies with the EHSRs, they will draw up and issue an 'EC type-examination certificate'.

Where Schedule 4 machinery has not been, or has only partly been, manufactured in accordance with harmonised standards, or where no such standards exist, then the technical file and an example of the machine must be submitted to an approved body for an EC type-examination.

An approved body is defined as "qualified persons". The key objective of the approved body is to ensure that relevant machinery which poses special hazards, is safe and complies with relevant the EHSRs. An example of an approved body is the Advanced Manufacturing Technology Research Institute (AMTRI) in Macclesfield Cheshire.

3.4 Requirements Of Other EU Directives

Machinery suppliers need to identify all other directives relevant to their products. Usually more than one directive may apply to a particular machine. For example, in addition to the EU Machinery Directive, an item of electrically driven machinery would be subject to the following: -

1. Electromagnetic Compatibility Directive 89/336/EEC as amended by 92/31/EEC. This was implemented in the UK as the Electromagnetic Compatibility Regulations 1992.
2. The Low Voltage Directive 72/23/EEC. This was implemented in the UK as the Electrical Equipment (Safety) Regulations 1992.

3.5 EU Declaration

3.5.1 Declaration Of Conformity

The supplier must draw up a EU "declaration of conformity" in order to confirm that the relevant machine complies with all the EHSRs that apply to it. The declaration must include a description of the machinery (with make, type and serial number), indicate all relevant provisions with which the machinery complies, give details of any certificate of adequacy or EC type examination. The declaration must identify the EN transposed harmonised standards applied in the design and construction of the machine. Other national and international standards relevant to the machine not covered by corresponding European standards should also be identified on the certificate (e.g. IEC 61508 'The functional safety of electrical/electronic/programmable electronic safety-related systems'). Reference should also be made to all other EU directives - for example Low Voltage Directive

73/23/EEC, Electromagnetic Compatibility Directive 89/339/EEC and the Simple Pressure Systems Directive 87/404/EEC (Raafat and Nicholas 1999).

A typical example of a declaration of conformity is shown in Figure 3.2.

3.5.2 Declaration Of Incorporation

Alternatively, where the machinery is intended for incorporation into another machine or assembly with other machinery to constitute machinery covered by the Directive, a 'declaration of incorporation' is required. The declaration of incorporation is identical to the declaration of conformity in respect to identifying relevant harmonised standards. The only differences are that the declaration of incorporation must include a condition that the equipment must not be put into service until the machinery into which it has been incorporated has been declared in conformity with the provisions of the EU Machinery Directive. There is no requirement for the declaration of incorporation to identify relevant EU directives.

Both the declaration of conformity and Incorporation must be translated into the native language of the country where the machinery is intended to operate.

Figure 3.2 Example Of EU Declaration Of Conformity

EU Declaration of Conformity

In accordance with: - **The Supply of Machinery (Safety) Regulations 1992**

We declare that this machine conforms with the Essential Health and Safety Requirements

Description of the machine, type and serial number: -

Business name and full address of manufacturer: -

All relevant **Product Directives** complied with: -

Machinery Directive (89/392/EEC), Low Voltage Directive (72/23/EEC) and EMC Directive (89/336/EEC) and all amendments thereto.

The machine complies with the following **Transposed Harmonised Standards**: -

EN 292-1, EN 292-2, EN 294, EN 349, EN954-1, EN 1050, EN 1088, EN 60204-1, ...

Other standards and technical specification utilised: -

IEC 61508

IDENTIFICATION of the person empowered to sign on behalf of the Company: -

Usually Managing Director

I certify that on 14th of January 1996 the above machine satisfies the EHSRs of all relevant product directives.

Signed... Date...........................

3.6 CE Marking

'CE' (Conformite European meaning European Conformity), marking on a product or system indicates a legal declaration by the supplier that the product or system complies with the EHSRs of the Machinery Directive and all relevant EU Directives.

The CE mark is regarded as properly affixed only if: -

1. EU declaration of conformity has been issued.
2. It is affixed in a distinct, visible, legible and indelible manner.
3. The machinery complies with the requirements of all other relevant directives.

It is an offence to affix the CE marking to machinery, which does not satisfy the EHSRs, or to machinery, which is not safe. The CE Mark consists of a symbol "CE", and the last two figures of the year in which the mark is affixed (Raafat and Nicholas 1999).

3.7 The Machine Is 'Safe'

The key objective of the EU Machinery Directive is that the onus is placed on suppliers to demonstrate that a machine complies with relevant EHSRs before it appears on the EU market.

Article 2(1) of the EU Machinery Directive states: "Member States shall take all appropriate measures to ensure that machinery covered by this Directive may be placed on the market place and put into service only if it does not endanger the health and safety of persons and, where appropriate, domestic animals or property, when installed and maintained and used for its intended purpose". This has been interpreted by the SMSR into a requirement that the machinery is in fact "safe". UK suppliers of machinery for use at work must also comply with the provisions of section 6 of the Health and Safety at Work etc Act 1974.

Some EU machinery suppliers appear concerned that the UK is, by the use of the term 'safe, imposing additional requirements and creating obstacles to the free movement of products in the EEA.

Regulation 2 of the SMSR defines "safe" as: "... when the machinery is properly installed and maintained and used for the purpose for which it was intended, there is no risk (apart from one reduced to a minimum) of it being the cause or occasion of death or injury to persons or, where appropriate, to domestic animals or damage to property..." It is further stated that the practicality at the time of manufacture of reducing the risk shall be taken into account when considering whether or not the risk has been reduced to a minimum. Neither the Department of Trade and Industry (DTI) guidance on the SMSR nor the Health and Safety Executive (HSE) booklet on supplying new machinery (HSE 1998) includes additional information on what is meant by "safe".

For the purposes of the research presented in this thesis, a working definition of 'safe' was adopted. This held that: "for machinery to be deemed safe, residual risks to health, safety and assets following control measures applied by the designers and manufacturers are reduced to a tolerable level for all foreseeable activities associated with the life cycle of the machine". This is arguably a less austere definition than the legal one, which appears to require even negligible risks to be reduced further if it is technically possible to do so, regardless of cost (Raafat and Nicholas 1999).

Failure to comply with EU requirements means that a machine cannot legally be supplied anywhere within the EEA. Such a failure by a UK supplier could result in summary prosecution leading to conviction of a fine of up to £5,000 or to a prison sentence of up to three months, or both. Similar sanctions exist throughout the EU.

This Chapter has charted the root to compliance for the EU Machinery Directive. It has examined the EHSRs and concludes that they are specified in general terms rather than specific measurable objectives In addition many of the EHSRs are duplicated throughout the various sections. It is anticipated that the proposed changes to the Directive will address these issues.

The root to compliance model laid out in Figure 3.1 will be utilised as a root map with which to examine compliance with the EU Machinery Directive. This will be the focus of Chapter 4 and Chapter 5.

The thesis will now move on to examine the results of the analytical survey.

Chapter 4: Analytical Survey

This is the first of two Chapters, which reports on the results of the empirical research findings.

The Chapter begins by detailing the results of the analysis of the declarations of conformity and incorporation, supplied by the 70 machinery suppliers. In addition it analyses the results of the smaller sample of 26 suppliers with regard to documentation and the task based risk assessment undertaken on their machinery.

This stage of the analysis was highlighted as a research objective and the approach adopted was outlined in the research methodology section of Chapter 1.

4.1 Compliance With Declaration And Marking Requirements

The study began with an analysis of the degree of suppliers' awareness of the EU requirements for procedures relating to declaration and CE marking. A breakdown of the type of declarations issued (if any) and whether CE markings were affixed is shown in Table 4.1. It has been derived from an analysis of Table 4.2.

Table 4.1 Type And Number Of Declarations Issued And Extent Of CE Marking

Type Of Declaration	Number	%	CE Marking			
			Yes	%	No	%
Conformity	48	68.5	43	61.4	5	3.1
Incorporation	12	17.2	Not applicable			
None	10	14.3	1	1.4	9	12.9

The analysis revealed that 61.4 per cent of suppliers surveyed had issued a declaration of conformity and had affixed the CE mark to their machines and 17.2 per cent of suppliers had issued a declaration of incorporation where CE marking is not required. Sixteen per cent of suppliers in the survey had no CE markings on their machinery when such was appropriate, while 14.3 per cent had failed to issue a declaration. It may be concluded at this stage that the majority of suppliers surveyed (78.6 per cent) demonstrated an awareness of the EU requirements relating to both declarations and CE marking (Raafat and Nicholas 1999).

Table 4.2 Relevant Documentation - Supply Stage

SUPPLIER	DESCRIPTION	SUPPLIED TO	COUNTRY	YEAR	TYPE OF DECLARATION	CE' MARKED
1. R&R ENG.	MULTI HEAD BORER	STANDARD PRODUCTS	UK	1997	NONE	NO
2. HOLFORD	ACCUMULATOR	STANDARD PRODUCTS	UK	1997	NONE	NO
3. NORMEC	RUBBER JOINING Mc	STANDARD PRODUCTS	NORWAY	1998	CONFORMITY	YES
4. CENCA	WELDING Mc	STANDARD PRODUCTS	UK	1997	CONFORMITY	YES
5. S.SCAN	PHOTO ELECTRICS	STANDARD PRODUCTS	UK	1998	CONFORMITY	YES
6. BENNETS	ABRASIVE CUTTER	STANDARD PRODUCTS	UK	1997	CONFORMITY	YES
7. P.C.P	SCRUBER UNIT	STANDARD PRODUCTS	UK	1997	CONFORMITY	YES
8. BETOL	FORMER	STANDARD PRODUCTS	UK	1998	CONFORMITY	YES
9. INMAM	TRIM RIG	STANDARD PRODUCTS	UK	1997	CONFORMITY	YES
10. MOTAN	HOPPERS	STANDARD PRODUCTS	FRANCE	1998	CONFORMITY	YES
11. GILLARD	METAL CUTTER	STANDARD PRODUCTS	UK	1997	CONFORMITY	YES
12. M&T	WELDER	STANDARD PRODUCTS	UK	1998	CONFORMITY	YES
13. SIGMA	CLINCHING Mc	STANDARD PRODUCTS	UK	1998	CONFORMITY	YES
14. UNILOY	INJ. MOULDER	TEXTRON	ITALY	1997	CONFORMITY	YES
15. S.P. ENG.	EXTRUSION LINE	STANDARD PRODUCTS	CANADA	1998	CONFORMITY	YES
16. PRECISION	CUTTER	STANDARD PRODUCTS	UK	1997	CONFORMITY	NO
17. FATA	ROBOTIC LINES	VAUXHALL MOTORS	ITALY	1996	NONE	NO
18. GERMA	ROBOT CELL	VAUXHALL MOTORS	GERMANY	1996	CONFORMITY	YES
19. GIBSON	MULTI WELD	VAUXHALL MOTORS	UK	1996	CONFORMITY	YES
20. FFT	WELDING PLANT	VAUXHALL MOTORS	GERMANY	1996	CONFORMITY	NO
21. COMAU	ROBOTIC LINES	VAUXHALL MOTORS	ITALY	1996	NONE	NO
22. TDC	ROBOTICS	VAUXHALL MOTORS	GERMANY	1996	CONFORMITY	YES
23. STEELWELD	ROBOT WELDERS	VAUXHALL MOTORS	NETHERLANDS	1997	CONFORMITY	YES
24. NOTHELFER	BODY ASS. EQUIP.	VAUXHALL MOTORS	GERMANY	1996	NONE	NO
25. BRITISH FED.	WELDER	VAUXHALL MOTORS	UK	1996	INCORPORATION	N/A

Table 4.2 Relevant Documentation - Supply Stage

SUPPLIER	DESCRIPTION	SUPPLIED TO	COUNTRY	YEAR	TYPE OF DECLARATION	CE' MARKED
26. KUKA	ROBOTICS	VAUXHALL MOTORS	SPAIN	1996	NONE	NO
27. CENTRELINE	PNEUMATIC GUARD	IBC VEHICLES	UK	1997	INCORPORATION	N/A
28. M. WEINGARTEN	MECH. PRESS	IBC VEHICLES	GERMANY	1997	CONFORMITY (ONLY WHEN ASKED)	NO
29. ST. CRANES	CRANE	IBC VEHICLES	UK	1998	INCORPORATION	N/A
30. ABB	ROBOTIC DESTACKER	IBC VEHICLES	SWEDEN	1997	INCORPORATION	N/A
31. ACT	CUTTER	STANDARD PRODUCTS	UK	1998	CONFORMITY	YES
32. LAZER	THERMAL HEATER	CARGILL	UK	1998	NONE	NO
33. ANACOM	WELDER	TEXTRON	UK	1998	NONE	NO
34. OMC SAL.	ACC.BALL VALVES	ETAP	ITALY	1997	CONFORMITY	YES
35. PREMABERG	UNION PUMPS	ETAP	UK	1997	INCORPORATION	N/A
36. BRUSH	ELECTRIC MOTORS	ETAP	UK	1997	INCORPORATION	N/A
37. RIDGE	COMPACT BENDERS	ETAP	BELGIUM	1995	CONFORMITY	YES
38. AJAX	LATHE	ETAP	UK	1997	CONFORMITY	YES
39. P.E.L.	GRINDER	TEXTRON	UK	1997	CONFORMITY	YES
40. BRISCO	WELLHEAD CONTROLS	ETAP	UK	1997	INCORPORATION	N/A
41. BARNSLEY	CRANE	ETAP	UK	1996	CONFORMITY	YES
42. MEDDINGS	MACHINE TOOLS	ETAP	UK	1997	CONFORMITY	YES
43. RJH	GRINDER	ETAP	UK	1996	CONFORMITY	YES
44. FRAMO	WATER INJ. PLANT	ETAP	NORWAY	1997	CONFORMITY	YES
45. N. PIGNONE	H. P. GAS COMP.	ETAP	ITALY	1996	INCORPORATION	N/A
46. P. CONTROL	PROCESSING EQUIP.	STANDARD PRODUCTS	UK	1996	CONFORMITY	YES
47. COREMA	MACHINE TOOLS	ETAP	ITALY	1996	CONFORMITY	YES
48. PROTEO	MACHINE TOOLS	ETAP	ITALY	1996	CONFORMITY (IN ITALIAN)	YES
49. S. MOTORI	MACHINE TOOLS	ETAP	ITALY	1996	INCORPORATION (IN ITALIAN)	N/A

Table 4.2 Relevant Documentation - Supply Stage

SUPPLIER	DESCRIPTION	SUPPLIED TO	COUNTRY	YEAR	TYPE OF DECLARATION	CE' MARKED
50. H.P.I.	BOTTLING EQUIP.	UNITED DISTILLERS	UK	1997	CONFORMITY	YES
51. CONSAFE	OIL PLATFORM	ETAP	UK	1998	CONF./INC. Global Approach	YES
					Machinery not specified.	
52. THOMAS INT.	GAS TURBINE	ETAP	NETHERLANDS	1997	CONFORMITY	YES
53. HAUNI	CIGARETTE MANUFACTURE	BAT	GERMANY	1997	CONFORMITY	YES
54. ADAM OPEL	MECHANICAL TRANS. PRESS	IBC VEHICLES	GERMANY	1997	CONFORMITY	YES
55. S.P.E	CUT TO LENGTH Mc.	STANDARD PRODUCTS	UK	1997	CONFORMITY	YES
56. VAN der LANDE	MATERIAL HAND. EQUIP.	BAT	NETHERLANDS	1997	CONFORMITY	YES
57. ATLAS TECH.	DIECARTS	IBC VEHICLES	USA	1997	INCORPORATION	N/A
58. FANUC	ROBOT PALLETISER	BAT	ITALY	1997	CONFORMITY	YES
59. HELU	ROBOTICS	VAUXHALL MOTORS	GERMANY	1997	INCORPORATION	YES
60. PROCTOR	GUARDS	VAUXHALL MOTORS	UK	1997	CONFORMITY	YES
61. DALMEC	MATERIAL TRANS. EQUIP.	VAUXHALL MOTORS	SWEDEN	1997	CONFORMITY	YES
62. E.MASCH	MACHINE TOOLS	VAUXHALL MOTORS	GERMANY	1997	CONFORMITY	YES
63. NETZSCH	HYDRAULIC PRESS	ALCAN CHEMICALS	GERMANY	1997	CONFORMIY (IN GERMAN)	NO
64. NORTH SEA COM	WASTE COMPACTOR	OFFSHORE INSTALLATION	UK	1997	NONE	NO
65. NOBLE ENG.	SACK SLITTER	OFFSHORE INSTALLATION	UK	1997	CONFORMITY	NO
66. AUTOMATED TRA	POTTERY TRANSFER EQU.	POTTERIES	UK	1998	CONFORMITY	YES
67. KOMATSU	MECH. PRESS	IBC VEHICLES	JAPAN	1997	INCORPORATION	N/A
68. G.G.COMP.	WASTE COMPACTOR	STANDARD PRODUCTS	UK	1998	CONFORMITY	YES
69. MARRYAT	PALLETISER	UNITED DISTILLERS	ITALY	1997	CONFORMITY	YES
70. MIDES	STACKER/PALLETISER	MACKAYS PLC	ITALY	1995	NONE	YES

Muller Weingarten No 28 only provided a declaration of conformity at the request of end user. The declaration did not state if the 2500 tonne press supplied had been subject to any third party accreditation. Proteo No 48, Netzsch No 63 and Salva-Motori No 49 had issued their declarations in their native language.

In another instance, Consafe No 51 had decided on a global approach to their declarations of conformity/incorporation i.e. one declaration, which encompasses numerous items of machinery.

4.2 Compliance With Relevant EU Directives

As stated previously, a declaration of conformity must indicate the legal provisions with which the machine complies. Thus, there should be reference not only to the Machinery Directive but also to any other directives relevant to the particular machine. Table 4.3 (derived from an analysis of Table 4.4) shows that only a minority of suppliers (25 per cent) provided a complete picture in this respect (Raafat and Nicholas 1999).

Table 4.3 Completeness Of Declarations With Respect To Relevant Directives

Directives Indicated	Percentage
All Relevant Directives Indicated	25
Not All Relevant Directives Indicated	60.4
No Relevant Directives Indicated	14.6

Table 4.4 Relevant Directives Indicated

SUPPLIER	DECLARATION	RELEVANT DIRECTIVES	MACHINERY DIRECTIVE	LOW VOLTAGE DIRECTIVE	EMC DIRECTIVE
1. R & R ENG	NONE				
2. HOLFORD	NONE				
3. NORMEC	CONFORMITY	INCOMPLETE	YES	NO	NO
4. CENCA	CONFORMITY	NONE			
5. S.SCAN	CONFORMITY	COMPLETE	YES	YES	YES
6. BENNETS	CONFORMITY	COMPLETE	YES	YES	YES
7. P.C.P	CONFORMITY	COMPLETE	YES	YES	YES
8. BETOL	CONFORMITY	INCOMPLETE	YES	NO	NO
9. INMAN	CONFORMITY	INCOMPLETE	YES	NO	NO
10. MOTAN	CONFORMITY	COMPLETE	YES	YES	YES
11.GILLARD	CONFORMITY	INCOMPLETE	YES	NO	NO
12. M&T	CONFORMITY	NONE			
13. SIGMA	CONFORMITY	COMPLETE	YES	N/A	N/A
14. UNILOY	CONFORMITY	INCOMPLETE	YES	NO	NO
15. S.P. ENG.	CONFORMITY	INCOMPLETE	YES		
16. PRECISION	CONFORMITY	INCOMPLETE	YES	YES	NO
17. FATA	NONE				
18. GERMA	CONFORMITY	INCOMPLETE	YES	NO	NO
19. GIBSON	CONFORMITY	INCOMPLETE	YES	NO	NO
20. FFT	CONFORMITY	INCOMPLETE	YES	NO	NO
21. COMAU	NONE				
22. TDC	CONFORMITY	INCOMPLETE	YES	NO	NO
23. STEELWELD	CONFORMITY	INCOMPLETE	YES	NO	NO
24. NOTHELFER	NONE				
25. BRITISH FED.	INCORPORATION	N/A			

Table 4.4 Relevant Directives Indicated

SUPPLIER	DECLARATION	RELEVANT DIRECTIVES	MACHINERY DIRECTIVE	LOW VOLTAGE DIRECTIVE	EMC DIRECTIVE
26. KUKA	NONE				
27. CENTRELINE	INCORPORATION	N/A			
28. M. WEINGARTEN	CONFORMITY	INCOMPLETE	YES	NO	NO
29. ST. CRANES	INCORPORATION	N/A			
30. ABB	INCORPORATION	N/A			
31. ACT	CONFORMITY	COMPLETE	YES	YES	YES
32. LAZER	NONE				
33. ANACOM	NONE				
34. OMC SAL	CONFORMITY	NONE			
35. PREMABERG	INCORPORATION	N/A			
36. BRUSH	INCORPORATION	N/A			
37. RIDGE	CONFORMITY	INCOMPLETE	YES	NO	NO
38. AJAX	CONFORMITY	INCOMPLETE	YES	NO	NO
39. P.E.L.	CONFORMITY	INCOMPLETE	YES	NO	NO
40. BRISCO	INCORPORATION	N/A			
41. BARNSLEY	CONFORMITY	INCOMPLETE	YES	NO	NO
42. MEDDINGS	CONFORMITY	NONE			
43. RJH	CONFORMITY	COMPLETE	YES	NO	NO
44. FRAMO	CONFORMITY	INCOMPLETE	YES	NO	NO
45. N. PIGNONE	INCORPORATION	N/A			
46. P. CONTROL	CONFORMITY	COMPLETE	YES	YES	YES
47. COREMA	CONFORMITY	INCOMPLETE	YES	NO	NO
48. PROTEO	CONFORMITY	INCOMPLETE	YES	NO	NO
49. S. MOTORI	INCORPORATION	N/A			
50. H.P.I.	CONFORMITY	INCOMPLETE	YES	NO	NO

Table 4.4 Relevant Directives Indicated

SUPPLIER	DECLARATION	RELEVANT DIRECTIVES	MACHINERY DIRECTIVE	LOW VOLTAGE DIRECTIVE	EMC DIRECTIVE
51. CONSAFE	CONFORMITY	INCOMPLETE	YES	NO	NO
52. THOMAS INT.	CONFORMITY	COMPLETE	YES	YES	YES
53. HAUNI	CONFORMITY	NONE			
54. ADAM OPEL	CONFORMITY	COMPLETE	YES	YES	YES
55. S.P.E.	CONFORMITY	INCOMPLETE	YES	NO	NO
56. VAN der LANDE	CONFORMITY	COMPLETE	YES	YES	YES
57. ATLAS TECH.	INCORPORATION	N/A			
58. FANUC	CONFORMITY	COMPLETE	YES	YES	YES
59. HELU	INCORPORATION	N/A			
60. PROCTOR	CONFORMITY	NONE			
61. DALMEC	CONFORMITY	INCOMPLETE	YES	NO	NO
62. E. MASCH	CONFORMITY	INCOMPLETE	YES	NO	NO
63. NETZSCH	CONFORMITY	INCOMPLETE	YES	NO	NO
64. NORTH SEA COMP.	NONE				
65. NOBLE ENG.	CONFORMITY	INCOMPLETE	YES	NO	NO
66. AUTOMATED TRANS.	CONFORMITY	INCOMPLETE	YES	NO	NO
67. KOMATSU	INCORPORATION	N/A			
68. G.G. COMP.	CONFORMITY	NONE			
69. MARRYAT	CONFORMITY	INCOMPLETE	YES	NO	NO
70. MIDES	NONE				

4.3 Awareness Of Relevant Harmonised Standards

An analysis of each declaration (conformity or incorporation) was carried out in order to compare the standards cited on the declaration certificate with the harmonised machinery safety standards applicable to the particular machine. Table 4.5 (derived from an analysis of Table 4.6) shows that few declarations included a complete list of relevant standards.

Table 4.5 Completeness Of Declarations With Respect To Relevant European Standards

EN Standards Indicated	Percentage
All Applicable EN Standards Indicated	6.7
Not All Relevant Standards Indicated	60
No Applicable EN Standards Indicated	33.3

The demonstration of compliance with the EHSR's for machinery through the application of relevant European harmonised standards is a crucial feature of the 'new approach'. It was noted that a significant proportion of machines were apparently designed and manufactured without reference to such standards. A significant majority of declaration certificates failed to identify relevant standards and many referred to standards that are now out-of-date. For example, 11 declarations made reference to the (now obsolete) 'Code of Practice for Safety of Machinery'

Table 4.6 EN Standards Indicated

SUPPLIER	RELEVANT STANDARDS	EN STANDARDS NOTED												
		EN 292-1 EN 292-2	EN 294 EN 349	EN 418	EN 574	EN 999 EN 50100	EN 953	EN 954-1	EN 982 EN 983	EN 1088	EN 1050	EN 60204-1	C' TYPE STANDARD	OTHER
1. R & R ENG.	NO DEC.				N/A	N/A			N/A				N/A	
2. HOLFORD	NO DEC.				N/A	N/A							N/A	
3. NORMEC	INCOMPLETE	*			N/A	N/A				N/A		*	N/A	
4. CENCA	NONE		N/A		N/A	N/A	N/A			N/A			N/A	
5. S. SCAN	INCOMPLETE	*			N/A	N/A			N/A	N/A		*	N/A	BS 5304
6. BENNETS	INCOMPLETE	*			N/A	N/A				N/A		*	N/A	BS 5304
7. P.C.P	NONE		N/A		N/A	N/A	N/A		N/A	N/A			N/A	HASAWA
8. BETOL	NONE				N/A	N/A				N/A			N/A	
9. INMAN	INCOMPLETE	*			N/A	N/A			N/A	N/A			EN 1550	
10. MOTAN	INCOMPLETE	*			N/A	N/A				N/A		*	N/A	
11. GILLARD	NONE				N/A	N/A				N/A			N/A	
12. M & T	INCOMPLETE	*	N/A		N/A	N/A	N/A			N/A		*	N/A	BS 5304
13. SIGMA	INCOMPLETE	*			N/A	N/A				N/A		*	N/A	
14. UNILOY	INCOMPLETE	*												
15. S.P. ENG.	INCOMPLETE	*			N/A	N/A				N/A				
16. PRECISION	NONE				N/A	N/A				N/A			N/A	
17. FATA	NO DEC.				N/A	N/A				N/A				
18. GERMA	INCOMPLETE	*			N/A	N/A						*		
19. GIBSON	INCOMPLETE	*			N/A	N/A			N/A	N/A		*	N/A	BS 5304
20. FFT	INCOMPLETE	*	*		N/A	N/A	*			N/A		*	N/A	
21. COMAU	NO DEC.				N/A	N/A								
22. TDC	INCOMPLETE	*	*		N/A	N/A	*					*		
23. STEELWELD	INCOMPLETE	*	*		N/A	N/A	*							
24. NOTHELFER	NO DEC.				N/A	N/A							N/A	

Table 4.6 EN Standards Indicated

SUPPLIER	RELEVANT STANDARDS	EN STANDARDS NOTED												
		EN 292-1 EN 292-2	EN 294 EN 349	EN 418	EN 574	EN 999 EN 50100	EN 953	EN 954-1	EN 982 EN 983	EN 1088	EN 1050	EN 60204-1	C' TYPE STANDARD	OTHER
25. BRITISH FED.	INCOMPLETE		N/A		N/A	N/A	N/A			N/A		*	N/A	
26. KUKA	NO DEC.				N/A	N/A				N/A				
27. CENTRELINE	INCOMPLETE	*	*		N/A	N/A	*			N/A			N/A	BS 5304
28. M. WEINGARTEN	INCOMPLETE	*			*	*		*				*		
29. ST. CRANES	INCOMPLETE	*			N/A	N/A				N/A		*		
30. ABB	COMPLETE	*	*	*	*	*	*	*	*	*	*	*	EN 775	
31. ACT	NONE				N/A	N/A				N/A			N/A	
32. LAZER	NO DEC.				N/A	N/A				N/A				
33. ANACOM	NO DEC.				N/A	N/A				N/A			N/A	
34. OMC SAL.	NONE				N/A	N/A				N/A			N/A	BS 5304
35. PREMABERG	NONE				N/A	N/A				N/A				
36. BRUSH	NONE				N/A	N/A				N/A			N/A	
37. RIDGE	NONE				N/A	N/A			N/A	N/A				
38. AJAX	INCOMPLETE	*			N/A	N/A			N/A	N/A		*		
39. P.E.L.	NONE				N/A	N/A				N/A				
40. BRISCO	INCOMPLETE	*			N/A	N/A				N/A		*		BS 5304
41. BARNSLEY	NONE				N/A	N/A				N/A				BS 5304
42. MEDDINGS	INCOMPLETE	*			N/A	N/A				N/A		*	N/A	BS 5304
43. RJH	NONE				N/A	N/A				N/A				BS 5304
44. FRAMO	INCOMPLETE	*			N/A	N/A				N/A				
45. N. PIGNONE	NONE				N/A	N/A				N/A				
46. P. CONTROL	NONE				N/A	N/A				N/A				
47. COREMA	INCOMPLETE	*			N/A	N/A				N/A		*	N/A	
48. PROTEO	INCOMPLETE	*			N/A	N/A				N/A		*	N/A	

Table 4.6 EN Standards Indicated

SUPPLIER	RELEVANT STANDARDS	EN STANDARDS NOTED												
		EN 292-1 EN 292-2	EN 294 EN 349	EN 418	EN 574	EN 999 EN 50100	EN 953	EN 954-1	EN 982 EN 983	EN 1088	EN 1050	EN 60204-1	C' TYPE STANDARD	OTHER
49. S. MOTORI	INCOMPLETE	*			N/A	N/A				N/A		*	N/A	
50. H.P.I.	INCOMPLETE	*			N/A	N/A						*		
51. CONSAFE	NONE				N/A	N/A								
52. THOMAS INT.	INCOMPLETE	*			N/A	N/A				N/A				
53. HAUNI	INCOMPLETE	*			N/A	N/A						*		
54. ADAM OPEL	COMPLETE	*	*	*	*	*	*	*	*	*	*	*	EN 692	
55. S.P.E.	INCOMPLETE	*	*		N/A	N/A	*	*		*		*		
56. VAN der LANDE	COMPLETE	*	*	*	*	*	*	*		*	*	*	EN 415	
57. ATLAS TECH.	INCOMPLETE	*			N/A	N/A				*		*		
58. FANUC	INCOMPLETE	*			*	*		*				*	EN 775	
59. HELU	INCOMPLETE	*			N/A	N/A						*		
60. PROCTOR	INCOMPLETE	*	*		N/A	N/A	*			N/A				
61. DALMEC	NONE				N/A	N/A				N/A				
62. E. MASCH	INCOMPLETE	*			N/A	N/A				N/A		*		
63. NETZCH	INCOMPLETE	*			N/A	N/A						*		
64. NORTH SEA COMP.	NO DEC.											N/A		
65. NOBLE ENG.	NONE				N/A	N/A								BS 5304
66. AUTOMATED TRANS.	NONE				N/A	N/A							N/A	
67. KOMATSU	COMPLETE	*	*	*	*	*	*	*	*	*	*	*	EN 692	
68. G.G.COMP.	NONE				N/A	N/A							N/A	
69. MARRYAT	INCOMPLETE	*			N/A	N/A				N/A		*		ISO 9000
70. MIDES	NO DEC.				N/A	N/A								

BS 5304: 1988. This, and other British standards, had been superseded by harmonised European standards by the date of supply. Hence, British standards alone can no longer be used to demonstrate compliance with all relevant EHSR's.

4.4 Analysis Of Year Of Supply

Analysis of Table 4.7 reveals that the 7 per cent of declaration certificates that indicated all relevant EN standards had been issued in 1997 (Raafat and Nicholas 1999).

Table 4.7 Analysis Of Year Of Supply

Year Of Supply	Number Of Machines	Declaration Of Conformity/ CE Mark		Declaration Of Incorporation		All Relevant EN Standards Indicated	
		Yes	%	Yes	%	Yes	%
1995	2	1	2.3	0	0		
1996	16	8	18.6	3	25		
1997	38	23	53.5	8	66.7	4	7
1998	14	11	25.6	1	8.3		

Further analysis indicates that 79.1 per cent of the declarations of conformity and 75 per cent of the declarations of incorporation had been issued between 1997 and 1998. This was well in advance of the deadline date of 1st January 1995, when all aspects of the EU Machinery Directive came into force and was consequently suitable data on which to base subsequent analysis and conclusions.

4.5 EN Standards Most Frequently Cited

The European standards most frequently cited on the declaration certificates surveyed are shown in Table 4.8.

Table 4.8 Standards Most Frequently Cited On Declarations As A Proportion Of The Number Of Machines To Which Standards Are Relevant

EN Standard	Number Of Citations	Number Of Relevant Machines	Percentage Correctly Cited
EN 292-1 and 2 (General Design Principles)	39	70	55.7%
EN 60204-1 (Electrical Equipment)	32	69	46.4%
EN 294/EN 349/EN 953 (Safeguards)	10	65	15.4%
EN 954-1 (Control Systems For Safety)	7	70	10%
EN 1088 (Interlocking Devices)	6	26	23.1%
EN 574 (Two-handed Controls/Safety Devices)	6	8	75%
EN 418 (Emergency Stops)	4	70	5.7%
EN 1050 (Principles For Risk Assessment)	4	70	5.7%
EN 982/983 (Hydraulic/Pneumatic)	3	60	5%
Relevant 'C' Type Standard Indicated	6	42	14.3%
British Standard BS 5304: 1088	*11*	-	-

This shows that 39 out of 70 suppliers made reference to EN 292 parts 1 and 2. EN 292 is an A-type standard that should be applied to all machinery. Despite this, nearly one half of the suppliers in the survey failed to mention it.

The second most frequently cited standard was EN 60204-1 'Safety of machinery - Electrical equipment of machines - General requirements', which relates to requirements for the safety of electrical equipment of machines. All but one of the machines in the survey was electrically driven, the one exception being a pneumatically powered waste compactor used on offshore installations. Table 4.8 shows that just 32 suppliers out of 69 (46.4 per cent) made correct reference to EN 60204-1 (Raafat and Nicholas 1999).

European standards relating to the construction of safeguards and safety distances to prevent danger zones being reached (EN 294 'Safety of machinery - Safety distances to prevent danger zones being reached by the upper limbs', EN 349 'Safety of machinery - Minimum gaps to avoid crushing of parts of the human body; and EN 953 'Safety of machinery - Guards - General requirements for the design and construction of fixed and movable guards') should be indicated when a physical safeguard is used. However, only 10 suppliers (15.4 per cent) made correct reference to these standards.

One of the most critical harmonised European standards applying to all machines with control systems is EN 954-1 'Safety of machinery - Safety-related parts of control systems - General principles for design'. Risk assessment is used in this standard (based on event tree analysis) in order to select one of four categories of integrity level. The majority of suppliers surveyed did not demonstrate a high level of compliance with this standard. Only seven suppliers out of 70 made correct reference to EN 954-1.

EN 1088 'Safety of machinery - Interlocking devices associated with guards - Principles for design and selection' is a key standard. Only six suppliers (23.1 per cent of machines with interlocking devices fitted) made correct reference to this standard. Once again, risk assessment plays an important role in deciding the type and integrity of interlocking devices.

A key EHSR is that, where appropriate, machinery should have emergency stop devices. EN 418 covers the design, selection, functional aspects and integrity of emergency stop devices 'Safety of machinery - Emergency stop equipment - Functional aspects, principles for design'. The level of risk should determine the integrity requirement for emergency stop devices circuitry. Only four suppliers (5.7 per cent) made correct reference to this standard.

When a physical safeguard is impracticable, machinery designers may rely on safety devices (e.g. electro-sensitive protective equipment or two-hand control devices). The harmonised standards for electro-sensitive protective devices EN 50100 'Safety of machinery - Electro-sensitive protective devices' and EN 999 'Safety of machinery

- The positioning of protective equipment in respect of approach speeds of parts of the human body', while the design of a two-hand control device is covered by EN 574 'Safety of machinery - Two-hand control devices - Functional aspects - Principles for design'. As indicated in Table 4.8, six out of the eight suppliers of machines fitted with such safety devices made correct reference to relevant standards. This was one of the more encouraging features of the survey.

If a machine or part of a process has no specific C-type standard associated with it, it would normally be expected that the supplier would carry out a risk assessment in accordance with EN 1050. Only four suppliers (5.7 per cent of the total) made correct reference to this standard. EN 1050 is probably the most crucial of the harmonised machinery safety standards, as it links hazards through a structured procedure for the evaluation of risks, enabling the proper selection of interlocking devices, control systems and emergency stop systems.

When machinery relies on fluid power systems for control or operation, then it would be expected that designers would make reference to EN 982 'Safety of machinery - Safety requirements for fluid power systems and their components - Hydraulics' and/or EN 983 'Safety of machinery - Safety requirements for fluid power systems and their components - Pneumatics'. The results of the survey suggest that these standards are not familiar to the suppliers sampled. Of 60 machines that contained elements of fluid power systems and/or components, only three suppliers (five per cent) made reference to either of these standards (Raafat and Nicholas 1999).

Where a relevant Type C harmonised standard exists for a particular class of machine, the supplier needs to identify such a standard and ensure its correct application. Although many of the machines indicated on suppliers' declarations of conformity had an associated C-type standard, only six suppliers out of 42 (14.3 per cent), made a correct reference.

One indicator of the lack of awareness of the risk-based approach to machinery safety and the role of directives was the erroneous inclusion of British standards for machinery safety. Eleven suppliers (16 per cent) made reference to British standards such as BS 5304: 1988 'Code of practice for safety of machinery', BS 4481: 1989 'Bonded abrasive products' and BS 2573: 1983 'Rules for the design of cranes'. One major supplier, Marryat, No 69, cited BS EN ISO 9001: 1994 'Quality systems - Specification for design/development, production and servicing' as the only transposed harmonised European standard used. This standard relates to quality systems and not machinery safety (Raafat and Nicholas 1999).

At this stage it was noted that the Italian supplier Fata No 17 was totally ignorant about its' legal obligations, consequently they had their contract with Vauxhall Motors terminated at the construction stage.

The British standards indicated on the suppliers' declarations couldn't be used as a basis for demonstrating compliance with relevant EHSRs for several reasons.

These include the following: -

1. All British standards cited had been replaced by the harmonised European standards by the dates these machines were supplied.
2. British standards have tended to be prescriptive and focus on guarding against physical injury (mechanical hazards), whereas the European standards are goal setting and consider a wider range of hazards e.g. mechanical, electrical, the neglect of ergonomic principles etc.
3. Although there was a reference in British Standard BS 5304: 1988 to the need to apply risk assessment at the design stage, this was largely ignored due to the lack of clarity and confusing guidance. This standard, however, contained useful guidance and illustrations for safeguarding techniques, which were used as a basis for the European standard EN 1088 on interlocking devices.
4. Many of the harmonised standards were produced in provisional form - shown as 'pr EN' - during the early part of this study (1995-96). CEN has indicated that provisional standards represent a final draft and the competed Standards will contain only minor modifications - of a textual rather than technical nature. Provisional standards therefore represent 'state of the art' technical information on the subject. Hence, even when harmonised standards were in their provisional form, they should have taken precedence over corresponding British standards. Some suppliers in the study did make correct reference to provisional European standards (Raafat and Nicholas 1999).

4.6 Inspection Of Documentation and Machinery

The second stage of the study singled out 26 suppliers for a more detailed analysis of the route of compliance with the EU requirements. This included physical inspection of both the documentation and machinery to verify the level of residual risk.

Table 4.9 identifies the country of origin of each of the 26 machines selected for this stage of the analysis, the type of machinery and the UK industry sector supplied.

Four items of machinery included in this sample are listed in Annex IV of the Machinery Directive (Schedule 4 of SMSR). These include an injection moulding machine (Uniloy No 14), a 2500t mechanical press (Muller Weingarten No 28), an aluminium filter press (Netzsch No 63) and a 25t mechanical press (Komatsu No 67).

Table 4.9 Sample Surveyed In Stage 2 Of The Study

Supplier	Country Of Supply	Type Of Machinery	Supplied To
1. R&R Eng.	UK	Multi-head Borer	Standard Products
2. Holford	UK	Accumulator	Standard Products
3. Normec	Norway	Rubber Joining Mc.	Standard Products
14. Uniloy	Italy	Injection Moulding Mc.	Textron
15. SP Eng.	Canada	Curing Oven	Standard Products
19. Gibson	UK	Robotics Multi-welding	Vauxhall Motors
22. TDC	Germany	Robotics Assembly	Vauxhall Motors
28. M. Weingarten	Germany	2500t Mechanical Press	IBC Vehicles
30. ABB	Sweden	Robotics de-stacker	IBC Vehicles
37. Ridge	Belgium	Compact Benders	ETAP
38. Ajax	UK	Centre Lathe	ETAP
41. Barnsley	UK	Overhead Crane	ETAP
43. RJH	UK	Grinding Machine	ETAP
45. N.Pignone	Italy	High Pressure Gas Comp.	ETAP
54. Adam Opel	Germany	Transfer Mechanical Press	IBC Vehicles
56. Van de Lande	Netherlands	Material Handling Equip.	BAT
57. Atlas Tech.	USA	Electro-hydraulic Diecarts	IBC Vehicles
58. Fanuc	Italy	Robotics Palletiser	BAT
61. Dalmec	Sweden	Material Transfer Equip.	Vauxhall Motors
63. Netzsch	Germany	Aluminium Filter Press	Alcan Chemicals
64. N. Sea Comp.	UK	Pneumatic Waste Comp.	Offshore Installation
65. Noble Eng.	UK	Sack Slitting Equipment	Offshore Installation
66. Automated Tran.	UK	Pottery Transfer Equip.	Potteries
67. Komatsu	Japan	25t Mechanical Press	IBC Vehicles
69. Marryat	Italy	Palletiser/De-palletiser	United Distillers
70. Mides	Italy	Printing Machine/Palletiser	Mackays PLC

4.7 Aspects Of Detailed Analysis

A summary of the detailed analysis of the extent of the 26 suppliers' compliance with EU requirements is shown in Table 4.10.

The analysis involved the inspection of documentation for each machine to assess the degree of compliance with relevant harmonised standards, and the standard of instructions for safe access during normal operation and other foreseeable activities, such as maintenance, testing, fault finding, setting and cleaning. Particular attention was afforded to instructions and documented procedures for safe installation and commissioning as many safety systems may have been defeated at this stage for 'inching, start up and adjustment' etc (Raafat and Nicholas 1999).

The last stage of the analysis involved the physical inspection of individual machines, including the level of integrity of the safeguards, interlocking devices, electrical system, emergency stop devices, safety related parts of control systems and other safety devices (Raafat and Nicholas 1999). It was at this stage that the task-based approach to risk assessment was utilised as set out in the research methodology Chapter 1.

Table 4.10 Compliance With Machinery Safety Requirements

Requirement	Number Of Relevant Machines	Compliance With Requirement			
		Yes	%	No	%
Risk assessment carried out	26	3	11.5	23	88.5
Risk assessment adequate/conforms with EN1050	3	2	7.7	1	3.8
Control system complies with EN 954-1 categories	26	3	11.5	23	88.5
Guards comply with EN 294/EN 349 (safety distances)	25	4	16	21	84.0
Hierarchy of risk control measures complies with EN 292-1	26	6	23.1	20	76.9
Guard interlocking devices conform with EN 1088	25	5	20.0	20	80.0
Emergency stop devices conform with EN 418/EN 954-1/ EN 60204-1	26	3	11.5	23	88.5
Guards constructed in accordance with EN 953	26	11	42.3	15	57.7
Safety of fluid power systems conforms with EN 982/EN 983	18	2	11.1	16	88.8
Electrical equipment conforms with EN 60204-1	25	14	56.0	11	44.0
Safety/trip devices conform with relevant B1/B2-type standards	17	5	29.5	12	70.5
Relevant C-type standard correctly indicated	15	5	33.3	10	66.6
Relevant C-type standard correctly used	5	2	13.3	3	20.0
Instructions for commissioning adequate	26	5	19.2	21	80.8
Instructions for safe systems of work adequate	26	8	30.8	18	69.2
Instructions for safe maintenance, setting, cleaning adequate	26	12	46.2	14	53.8
Safe access provided for normal operation of machine	26	14	53.8	12	46.2
Safe access provided for maintenance, setting, cleaning	26	5	19.2	21	80.8
Warning notices adequate	26	9	34.6	17	65.4
Declaration certificate issued	26	22	84.6	4	15.4
Declaration certificate adequate	22	5	19.2	17	65.4
CE marking affixed to machine	21	15	71.4	6	28.6
Technical file constructed	26	3	11.5	23	88.5
Technical file complies	3	1	3.8	2	7.7
The machine is 'safe' (residual risks tolerable)	26	4	15.4	22	84.6

4.8 Results Of Detailed Analysis

1. Risk Assessment

Three suppliers out of 26 indicated on their declarations of conformity that they had carried out a risk assessment. Only two risk assessments (7.7 per cent) were judged to be adequate as they complied with the requirements of EN 1050.

Although a C-Type Standard may apply to certain parts of 15 pieces of machinery in the sample studied, it is still necessary to consider the application of EN 1050 due to the way in which these machines are designed, constructed and operated, and interfaced with other processes.

2. Control Systems With Safety Related Functions

Only three suppliers (11.5 per cent) demonstrated correct compliance with EN 954-1 by using risk assessment to select the appropriate category of control system integrity.

This Standard has, incidentally, received wide criticism for being almost incomprehensible. It has been the subject of much internal discussion within CEN. In view of this, it is perhaps unsurprising that few suppliers make reference to this standard.

3. Standard Of Safeguards

Four suppliers (16 per cent) demonstrated the correct application of all relevant standards relating to the safety distances and minimum gaps associated with safeguards (e.g. EN 294 and/or EN 349).

Eleven suppliers (42.3 per cent) complied with EN 953, which concerns design and construction requirements.

4. Hierarchy Of Risk Control Measures.

The procedures to be followed by machinery suppliers are clearly defined under EN 292-1. These are summarised as follows: -

To define intended and foreseeable uses for the machine, including installation, use and maintenance through to decommissioning and disposal;

To assess all hazardous situations in the various states of the machine; For each identified hazard and hazardous situation, to consider sequentially the following questions, until the goal of adequate safety is achieved: -

A. Is hazard avoidable? *Hazard elimination in design*

B. Is risk reducible? *Risk reduction in design*

C. Is safeguarding possible? *Safeguarding techniques*

D. Is safety adequate? *Instructions, safe systems, warnings*

Analysis of the results of the inspection showed that only six suppliers (23.1 per cent) demonstrated correct compliance with the above requirements. The majority of other suppliers appeared to rely on purchasers of machinery developing their own safe systems of work and isolation procedures as the first option for risk reduction.

5. Guard Interlocking Devices

The survey indicated that five suppliers (20 per cent) correctly implemented, where relevant, the requirements of EN 1088 for interlocking devices associated with guards. Other suppliers of machines with interlocking elements did not specify EN 1088 and in nearly all cases the standard of interlocking was judged to be less than adequate in relation to the level of risk.

6. Emergency Stop Devices

Three suppliers (11.5 per cent) specified and correctly applied EN 418. The design of emergency stop devices needs also to consider the link with other standards, (e.g.

EN 954 -1 and EN 60204 -1 relating respectively to control systems and electrical equipment).

7. Fluid Power Systems Safety

Whenever a part of machinery or its power or control systems is operated by fluid power, it would be expected that reference be made to EN 982 (hydraulics) and/or EN 983 (pneumatics). Two suppliers out of 18 (11.1 per cent) correctly referred to and applied the provisions of these standards.

8. Electrical Equipment Safety

The results confirm the findings of the first part of this study i.e. one of the standards most frequently cited. The majority of suppliers (56 per cent) had applied EN 60204-1 correctly to their machinery.

9. Safety Systems: Trip Devices And Two-hand Controls

The correct application of B1- and B2-type standards relevant to safety device, including EN 999 (positioning of protective equipment), EN 50100 (electro-sensitive protective devices) and EN 574 (two-hand control devices), was demonstrated by five of the 17 suppliers of machines fitted with such devices.

10. C-Type Standards

Five suppliers out of 15 made reference to C-type standards in their declaration certificates. However, closer inspection revealed that only two of these demonstrated the correct application of these standards.

11. Standard Of Instructions

The standard of supplier's instructions was analysed with respect to three activities: -

1. Installation and commissioning of machinery.
2. Normal use.
3. Maintenance, setting, adjusting, fault finding, cleaning, and similar.

The analysis showed that five suppliers (19.2 per cent) provided adequate instructions for the safe installation and commissioning. The instructions for safe systems of work and for maintenance activities were judged to be significantly better than those for commissioning. Adequate instructions for normal use were provided by 30.8 per cent of suppliers and instructions for maintenance by 46.2 per cent.

12. Safe Access/Warning Notices

Fourteen (53.8 per cent) items of machinery were judged to have safe access for normal operations. However safe access for setting, maintenance and cleaning etc. was only provided on five (19.2 per cent) items of machinery.

Nine suppliers (34.6 per cent) had provided warning notices that were judged by the analyst to be adequate.

13. Technical File

A technical file drawn up to comply with regulation 13 SMSR (or regulations 14 or 15 with respect to Schedule 4 machinery) does not have to be made available to the end user. Indeed, regulation 24 states that the relevant documents do not have to be kept as a single, permanent file provided that they are all available individually and can be assembled into a technical file.

An attempt was made in this study, which proved to be a lengthy and difficult task, to find evidence that each supplier held a technical file. Only three suppliers out of 26 (11.5 per cent) demonstrated that some form of a technical file existed for the machinery. Closer inspection of the technical files revealed that only one supplier, complied with the requirements of a technical file in accordance with regulations 13, 14, or 15 of SMSR.

The particular supplier Komatsu is based in Japan. It had been issued with an attestation of conformity by one of the Department of Trade & Industry Approved Bodies (The Advanced Manufacturing Research Institute (AMTRI)). A technical file would therefore have to be drawn up for the approved body to examine.

14. The Machine Is 'Safe'

The final part of the analysis was to conduct a physical inspection of the 26 pieces of machinery. The criteria used for this examination took account of the items listed in Table 4.10. The inspection therefore extended beyond looking for obvious hazards. The key machine safety features included: -

a. The adequacy of the construction and safety distances of safeguards.

b. The adequacy, reliability and ease of defeat of interlocking devices.

c. The hazards, which could create intolerable, risk.

d. The selected integrity level of the control system.

e. Electrical equipment conformity with EN 60204-1.

f. Application of the hierarchy of risk control measures.

g. The design and locations of emergency stop devices.

h. The design and locations of safety/trip devices.

i. Safe access provided for routine and non-routine activities.

j. Instructions provided for normal operation as well as maintenance, setting, fault finding, cleaning and other foreseeable activities.

k. Compliance with Low Voltage and Electromagnetic Compatibility Directives.

l. The adequacy and appropriateness of warning notices.

The inspections and task-based risk assessments showed that only four of the 26 machines (15.4 per cent) met the criterion that residual risks (after the application of the manufactures'/suppliers' risk control measures) were tolerable. Details of the machinery judged to be 'safe' are shown in Table 4.11.

One of the machines was judged to be 'safe' despite the fact that the supplier had complied with only a number of prescriptive and outdated British standards.

Three of the machines had been supplied in 1997 and one in 1996.

Table 4.11 Suppliers Of The 'Safe' Machinery

Supplier (Country)	Year	Type of Machinery	Supplied To
30. ABB (Sweden)	1997	Robotics De-stacker	IBC Vehicles
41. Barnsley (UK)	1996	Overhead Crane	ETAP
56. Van der Lande (Netherlands)	1997	Material Handling Equip.	BAT
67. Komatsu (Japan	1997	Mechanical Press	IBC Vehicles

The findings of this study showed that the majority of the 70 machinery suppliers surveyed (85.7 per cent) have an awareness of the EU requirements relating to the two types of declaration (conformity and incorporation). A proportion of these (five suppliers), however, had failed to follow this through by affixing the required CE marking to their machines.

Analysis of the degree of compliance with the CE marking requirements showed that only 25 per cent of declarations correctly indicated all EU product directives relevant to the machinery in question.

The majority of suppliers surveyed (93.3 per cent) failed to recognise the crucial role of the European transposed harmonised standards in meeting the EHSRs. Sixty per cent of suppliers omitted relevant key European standards from their declarations, while 33.3 per cent demonstrated a lack of understanding of these standards.

Detailed analysis of the degree of compliance demonstrated by the 26 suppliers revealed some serious shortcomings. In addition physical inspection and sample task-based risk assessment of the 26 items of machinery revealed that only four items were judged by the analyst to be 'safe' (Raafat and Nicholas 1999).

4.9 Summary Conclusion

Initial findings from this study showed that the majority of the 70 machinery suppliers surveyed (85.7 per cent), have an awareness of EU requirements relating to the two types of declaration (conformity and incorporation). A proportion of these (8.2 per cent), however, had failed to follow this through by affixing the required CE marking to their machines.

Analysis of the degree of compliance with CE marking requirements showed that only 26 per cent of declarations correctly indicated all EU product directives relevant to the machinery in question.

The majority of suppliers surveyed (93 per cent) failed to recognise the crucial role of European transposed harmonised machinery safety standards in meeting the EHSRs. Sixty one per cent of suppliers omitted relevant key European standards from their declarations, while 32 per cent demonstrated a lack of understanding of these standards.

This maybe due to the complex structure of the harmonised standards, and/or less than adequate training in both machinery safety and risk assessment methodologies. Whatever the reason, many suppliers showed a lack of understanding of a risk-based approach to machinery safety (Raafat and Nicholas, 1999).

Detailed analysis of the degree of compliance demonstrated by 26 suppliers revealed some serious shortcomings. These can be summarised as follows: -

1. Only two suppliers (7.7 per cent of the sample studied) carried out an adequate risk assessment in accordance with EN 1050.
2. Fewer than 12 per cent of suppliers were able to demonstrate the correct application of EN 954-1 (safety-related parts of control systems).
3. Fewer than 14 per cent of relevant suppliers were able to apply correctly a relevant C-type standard.
4. Only 16 per cent of relevant suppliers were able to demonstrate that safety distances for safeguards complies with the requirements of EN 294 and EN 349.
5. Fewer than 20 per cent of suppliers provided safe access for maintenance, setting, adjusting, faultfinding and cleaning activities.
6. Fewer than four per cent of suppliers appeared to have constructed a technical file, which met the requirements of the SMSR.

Physical inspection and sample task based risk assessment of the 26 items of machinery revealed that only 4 items were judged by the analyst to be "safe".

The thesis will now move on to consider the root causes for non-compliance with the EU Machinery Directive.

Chapter 5: Root Causes For Non-compliance With EU Machinery Directive

This Chapter contains an analysis of the root causes for non-compliance with the EU Machinery Directive and SMSR. The results were derived from the 26 semi-structured interviews undertaken.

This stage of the analysis was highlighted as a research objective and the approach adopted was outlined in the research methodology section of Chapter 1.

The information provided by the interviewees was transcribed onto the field research work sheets shown in Appendix 3.

5.1 Semi-structured Interview Results

The results shown in Table 5.1 have been derived from an analysis of the field research work sheets shown in Appendix 3. An analysis of Table 5.1 has revealed the following root causes for non-compliance with the EU Machinery Directive and SMSR requirements (Raafat and Nicholas 2001): -

Table 5.1 Analysis Of Root Causes For Non-compliance With EU Requirements (26 Suppliers)

Description	Number Of Times	%
1. Finds the EN Standards complicated and confusing	24	92.3
2. Unaware of the requirement that risk assessment should cover the life cycle of the machine	24	92.3
3. Did not/could not provide a risk assessment	23	88.5
4. Unaware of the requirement that the design should accommodate foreseeable misuse	23	88.5
5. Unsure as to which EN Standards apply to their product	22	84.6
6. Unaware of the specific requirements for EN 1050	22	84.6
7. Unaware of the requirement for and content of a Technical File	22	84.6
8. Unaware of the EN Standards which require risk assessment	22	84.6
9. The EN Standards do not provide adequate guidance for designers	22	84.6
10. Unaware of relevant Essential Health and Safety Requirements (EH&SRs)	21	80.8
11. Insufficient/No training on machinery risk assessment	21	80.8
12. Unaware of role of European standards e.g. B1 and B2 Type	20	76.9
13. Unaware of the suppliers legal position if found not to comply	19	73.1
14. Unaware of the correct structure and content of the conformity assessment procedure	19	73.1
15. Insufficient/No training on relevant Legislation and Standards	18	69.2
16. Unaware of other EU Directives relevant to machine	18	69.2
17. Unaware that safe systems of work need to be documented for the installation and commissioning stages	17	65.4
18. Standards/documentation as a Quality Systems function	16	61.5
19. Unaware of the structure of the Transposed Harmonised Standards	15	57.7
20. Unaware of the requirements of the EU Machinery Directive	11	42.3
21. Assume that pr EN Standards do not apply as they are provisional	11	42.3
22. Unclear when a CE-mark should be affixed	10	38.5
23. Unaware of the need to provide safety instructions for access into machine for maintenance,setting, adjusting, fault finding, cleaning etc.	9	34.6
24. Assume that British Standards satisfy EH&SR's	8	30.8
25. Unaware of the difference between Declarations of Conformity and Incorporation	8	30.8
26. Supplier management did not provide Standards for designers	7	26.9
27. Assumes that 'CE' Marking and Declaration Certificates is a customer requirement	2	7.7

1. Complexity Of Harmonised EN Standards

In 24 (92.3 per cent) instances interviewees stated that they found the EN standards both complicated and confusing. Typical comments included "they require constant referencing and cross referencing with other standards" and "they are too numerous to mention".

2. Risk Assessment

Twenty four (92.3 per cent) respondents were unaware of the fact that a structured and systematic risk assessment encompassing the life cycle of the machine should be undertaken, in the absence of a 'C' type standard.

Comments included "why do we have to consider decommissioning, surely that's the end users responsibility".

Twenty three (88.5 per cent) of those interviewed either did not or could not provide a structured and systematic risk assessment.

A typical response was "why do we need to do a risk assessment when we have been building these for years".

3. Compliance With Essential Health And Safety Requirements

In 23 (88.5 per cent) instances respondents were unaware that the design of the machine should accommodate foreseeable misuse.

Three suppliers said, "why do we have to consider the idiots who may put their hands into moving parts".

4. Selection Of Appropriate EN Standards

On 22 (84.6 per cent) occasions it was concluded that respondents were unsure as to which EN standards applied to their particular products.

Typical comments included "there are far to many standards to select".

5. Specific Requirements Of EN 1050

In 22 (84.6 per cent) instances, it was noted that interviewees were unaware of the specific requirements of the risk assessment standard EN 1050.

Eleven suppliers commented on the fact that EN1050 does demonstrate how risk assessment is undertaken in practice. While the other eleven were all confused by the pr status of the standard.

6. Technical File

On 22 (84.6 per cent) occasions respondents were unaware of the requirement for and contents of, a technical file.

Responses included "where do we find a list of contents for a technical file".

7. EN Standards Requiring Risk Assessment

On 22 (84.6 per cent) occasions respondents were unaware as to which of the EN standards require a risk assessment to be undertaken.

Responses included "we are unsure which standards require risk assessment".

8. Adequate Guidance Of EN Standards

Twenty two (84.6 per cent) respondents concluded that the EN standards did not provide adequate guidance for designers.

Typical comments included "if we are supposed to use the standards, then we require information at our fingertips".

9. Relevant Essential Health And Safety Requirements

Respondents were unaware of relevant EHSRs in 21 (80.8 per cent) instances.

Typical responses included "the EHSRs are far too generic and are duplicated".

10. Risk Assessment Training

Further analysis of the responses has revealed that training in machinery risk assessment was either insufficient or had not been provided in 21 (80.8 per cent) instances.

Typical responses included "the last training I had was when I did my apprenticeship", "the boss gives us some information to read", and "its sink or swim in our organisation".

11. B1 And B2 Type European Standards

On 20 (76.9 per cent) occasions interviewees were unaware of the role both 'B1' and 'B2' type standards.

All 20 were unaware that these standards provided generic safety guidance/ information and the requirements for safety devices/safeguards (hardware/software).

12. Legal Responsibilities

On 19 (73.1 per cent) occasions, respondents were unaware of the suppliers legal position if found not to comply with all aspects of the requirements of the EU Machinery Directive.

Comments included "it's the problem of the end user" and "I have got no idea whatsoever".

13 Conformity Assessment Procedure

On a total of 19 (73.1 per cent) occasions it was concluded that interviewees were unaware of the correct structure and content of the conformity assessment procedure for their particular product.

Typical responses included "what's a conformity assessment" and "what do you mean by conformity assessment".

14. Legislation And EN Standards Training

On 18 (69.2 per cent) occasions it was concluded, that training was either insufficient or had not been provided on all aspects of both machinery legislative requirements and appropriate EN standards.

Responses mirrored the ones provided in the section on risk assessment training.

15. Other Relevant EU Directives

Further analysis of the responses has revealed that on 18 (69.2 per cent) occasions interviewees were unaware of other relevant directives, which applied to their machinery. For example the Electromagnetic Compatibility and Low Voltage Directives.

Responses included "what do you mean by other directives" and "I have never heard of them".

16. Documentation Of Safe Systems Of Work

Analysis of the results has revealed that respondents were unaware that safe systems of work needed to be documented for the installation and commissioning stage on 17 (65.4 per cent) occasions.

The suppliers concluded that they have been installing machines for years, "why do we require safe systems of work".

17. EU Standards/Documentation

On 16 (61.5 per cent) occasions analysis of the responses has revealed that the interviewees considered that compliance with EU standards/documentation was, in effect a documented quality systems function, undertaken after the design/construction of the machinery.

Comments included "the quality department are in charge of this".

18. Structure Of EN Standards

In 15 (57.7 per cent) instances interviewees were unaware of the structure of the transposed harmonised standards. In effect, they were unable to differentiate between 'A', 'B' and 'C'-type EN standards.

Comments included "the standards are totally confusing" and "why do we need all these different types".

19. EU Machinery Directive

On 11 (42.3 per cent) occasions, respondents were totally unaware about the EU requirements in relation to machinery safety.

Responses included "I have not got a clue" and "is this something new for the future".

20. Provisional EN Standards

Eleven (42.3 per cent) interviewees assumed that pr EN standards did not apply due to the fact that they were provisional.

Typical comments included "surely provisional means just that and we don't have to use them".

21. Requirement To 'CE' Mark

When asked about when the 'CE' mark should be affixed, 10 (38.5 per cent) respondents were unsure. In effect they were unable to differentiate between 'stand alone' and 'incorporated' items of machinery.

Responses included "we stick a CE Mark on everything" and "it depends whether the stores has any stickers".

22. Safety Instructions For Maintenance Etc.

Additional analysis has revealed that 9 (34.6 per cent) respondents were unaware of the requirement to provide safety instructions, which took into consideration maintenance, setting, adjusting, faultfinding and cleaning tasks.

Responses included "surely its up to the end user to provide these".

23. Use Of British Standards

Eight (30.8 per cent) respondents assumed incorrectly that it was possible to satisfy the EHSRs through the use of prescriptive and obsolete British standards such as BS 5304: 1988 'Safety of machinery'.

All of them commented that BS 5304 was a 'good book' as it provided all of the information under one umbrella and anyway you can still purchase the book so it must be usable.

24. Declarations Of Conformity/Incorporation

On 8 (30.8 per cent) occasions it was concluded from the responses that interviewees were unaware of the different declaration certificates.

Typical responses included “we copy the declarations supplied to us”.

25. Provision Of EN Standards

On 7 (26.9 per cent) occasions it was identified from the analysis that supplier management did not provide relevant EN standards to the designers.

Comments included “surely its down to the designer”.

26. Safety Instructions For Operators

On 2 (7.7 per cent) occasions, interviewees assumed that compliance with CE marking and the supply of declaration of conformity/incorporation was a customer requirement.

Typical responses included “its up to the customer what he wants”, and “we do what we are told and/or asked to do”.

5.2 Additional Analysis Of Root Causes

5.2.1 The EU Machinery Directive

The significant contributory causes for failure to comply with the EU Machinery Directive are shown in Table 5.2 (Raafat and Nicholas 2001).

An analysis of Table 5.2 reveals that the three contributory factors (above 10 per cent) relate to the role of risk assessment in compliance with the provisions of the Machinery Directive. These include the lack of understanding and application of risk assessment.

Table 5.2 Significant Contributory Causes For Failure To Comply With EU Directive

Response Number	Description	Percentage
2	Unaware risk assessment should cover the life cycle of the machine.	10.60%
3	Inadequate/no risk assessment.	10.20%
4	Design should accommodate foreseeable misuse.	10.20%
7	Unsure of content of technical file.	9.70%
10	Unaware of relevant EHSRs.	9.30%
13	Unaware of legal position if fails to comply with EU Machinery Directive.	8.40%
14	Unaware of structure of conformity assessment procedure.	8.40%
17	Unaware that safe system of work need to be documented.	7.50%
16, 20,22, 23, 25, & 27	Others.	25.70%
TOTAL		**100%**

5.2.2 The EN Harmonised Machinery Safety Standards

Table 5.3 reveals the significant contributory causes for failure to comply with the EN standards (Raafat and Nicholas 2001).

The data clearly indicates that there is wide spread confusion by most interviewees about the complex structure and the non-prescriptive nature of the EN standards.

The role of risk assessment within the European standards was also highly significant. Twenty six per cent of contributory causes within this category had related to the lack of understanding specific requirements of EN 1050, particularly the hazards identification checklist.

The lack of knowledge of other EN standards that require the application of risk assessment, e.g. EN 292-1 and EN 954-1, equated to 13.3 per cent of contributory causes.

Other contributory causes of equal significance (13.3 per cent) include the unclear guidance provided by relevant EN standards, and the designers' inability to select all relevant EN standards in relation to a particular product.

Table 5.3 Significant Contributory Causes For Failure To Comply With EN Standards

Response Number	Description	Percentage
1	EN standards found too complicated and confusing.	14.10%
5	Unsure as to which EN standards applied to their product.	13.30%
6	Unaware of the requirements of EN 1050.	13.30%
8	Unaware of the EN standards which require risk assessment.	13.30%
9	EN standards do not provide clear guidance.	13.30%
12	Unaware of the role of B1 and B2 type standards.	12%
19	Unaware of structure of EN standards.	9%
21	Assume that pr standards do not apply.	6.60%
24	Assumes that British standards satisfy EHSRs.	4.80%
	TOTAL	**100%**

In the absence of a relevant C-type EN standard, it is expected that designers (following on from there risk assessment), should rely on the generic guidance offered by B1 and B2 type standards. The survey has shown that 12 per cent of responses in this category have failed to recognise the role of these standards.

5.2.3 Designer, Manufacturer And Supplier Management Systems

The significant contributory causes for problems identified in relation to the designer, manufacturer and supplier management systems is shown in Table 5.4.

The most significant contributory cause to the lack of compliance with the Machinery Directive in this category was identified as the inadequate/lack of training on risk assessment (34 per cent) (Raafat and Nicholas 2001).

Table 5.4 Significant Contributory Causes Relating To Supplier Management Systems

Response Number	Description	Percentage
11	Inadequate/no training on machinery risk assessment.	34.00%
15	Inadequate/no training relevant legislation and standards.	29.00%
18	See compliance with EU requirements as a quality assurance responsibility.	25.00%
26	Relevant standards not provided to designers.	12.00%
	TOTAL	**100%**

This is followed by the inadequate/lack of training on the EU machinery safety legislation and standards (29 per cent).

The third contributory cause in this category was seen by some suppliers that the conformity assessment procedure/documentation was a quality assurance function carried out after the design/construction stages, rather than during the design/construction (25 per cent).

5.3 Summary Conclusion

Analysis of the responses from the root cause analysis has revealed the following: -

1. More than 92 per cent of suppliers' were unaware that the risk assessment process should encompass the life cycle of the machine.
2. More than 88 per cent either did not or could not undertake a risk assessment. In addition they were unaware that the design of the machine should accommodate foreseeable misuse.
3. More than 92 per cent of suppliers' found the EN standards both complicated and confusing.
4. More than 84 per cent were unsure as to which EN standard applied to their product, unaware of the specific requirements of EN 1050 and were unaware which EN standards require risk assessment to be undertaken. In addition more than 84 per cent concluded that the EN standards do not provide clear guidance to designers.
5. More than 80 per cent confirmed that they had received either inadequate or no training in risk assessment and over 69 per cent had received inadequate or no training in machinery legislation and standards.

The root cause analysis can be summarised into three key areas of concern (Raafat and Nicholas, 2001). These are: -

1. The lack of compliance with the provisions of the EU Machinery Directive.
2. The lack of application of the European machinery safety standards.

3. Serious issues relating to the suppliers' management systems.

The thesis will now move on to discuss the results of the empirical research findings.

Chapter 6: Discussion

This Chapter contains the discussion and interpretation of the empirical research findings, which were described in Chapter 4 and Chapter 5.

6.1 EU Documentation Requirements

The vast majority of suppliers (78.6 per cent) sampled in this study demonstrated an awareness of the EU Machinery Directive, in so much that they had issued a declaration certificate and affixed the CE mark to their product, where appropriate.

However, further analysis revealed that only 25 per cent of suppliers had correctly referenced all relevant EU directives on their declarations of conformity and only 6.7 per cent had correctly referenced all of the appropriate transposed EN standards, on their declarations of conformity and incorporation.

It became apparent that while the vast majority of suppliers were clearly aware of the EU Machinery Directive, they were uncertain as to how these requirements were implemented in practice.

6.1.1 Declaration Certificates And CE Marking

The root cause analysis revealed that 7.7 per cent of suppliers assumed incorrectly that CE marking and declaration certificates were a customer requirement. In addition 42.3 per cent were unaware of the specific requirements of the EU Machinery Directive. Similarly 38.5 per cent of those canvassed were unclear as to when the CE mark should be affixed and 30.8 per cent were unaware of the difference between a declaration of conformity and incorporation.

The root cause analysis also revealed that 69.2 per cent of suppliers were unaware of other relevant directives applicable to their products, which must be indicated on the declaration of conformity.

One German supplier Muller Weingarten No 28, who were responsible for the largest piece of machinery, a 2500 tonne mechanical press, should have provided a declaration of conformity at the supply stage. However, the documentation was only provided when the end user made a request. Mechanical presses require either a certificate of adequacy, or an EC-type examination certificate by an approved body, due to the fact that they pose 'special hazards'. Muller Weingarten did not fulfill the third party accreditation requirements.

Suppliers have a general duty to ensure that the declarations of conformity/incorporation are translated into the native language of the country where the machinery is intended to operate. Two of the suppliers who had provided declarations of conformity (Proteo No 48 and Netzsch No 63) and one who had provided a declaration of incorporation (S/Motori No 49) had issued their documentation in their native language.

In another instance Consafe Engineering No 51, a main oil platform design contractor, decided on a 'global' approach to the issue of declarations. The solitary declaration issued did not specify which machinery was supplied or by which sub-contractor. Given the fact that their machinery was unspecified, it was impossible to ensure compliance with the EU Machinery Directive. This type of declaration can only be described as meaningless.

It was noted that the reasons for this non-conformance is that 69.2 per cent of the suppliers interviewed indicated that they had either received insufficient, or no, training in relevant legislative requirements (e.g. EU Machinery Directive etc.).

6.1.2 EN Standards Indicated

A disappointing discovery was that only 6.7 per cent of suppliers had indicted all relevant EN standards on their declaration certificates. The root cause analysis revealed that 92.3 per cent of suppliers found the EN standards both complicated and confusing. It was also revealed that 84.6 per cent of those canvassed were unsure as to which of the EN standards applied to their products. It is noted that the reasons for this non-conformance are twofold.

Firstly, the analysis has shown that the EN standards are both complicated and confusing due to the fact that they require constant cross-referencing with other appropriate EN standards. For example EN 201:1997 which is the C-type EN standard for injection moulding machines requires constant cross referencing with other key EN standards such as EN 292-1:1991, EN 294:1992, EN 1088:1995, etc. Anyone designing and constructing machinery must be provided 'to hand' with all of the relevant information they require from the onset. Currently it is possible for the designer to purchase/access a C-type EN standard which is specific to a particular type or class of machine, only to discover when they read it that they require other A and B-type EN standards.

Upon inspection it is possible to note that certain EN standards contain inadequate guidance e.g. they do not indicate a methodology for ensuring compliance with the requirements contained therein. The European Committee for Standardisation (CEN) has already identified this problem, in so much that they have produced a route map for EN 60204-1. Suppliers knowledge of, and their degree of non-conformance in implementing the electrical standard, is significantly lower than with other EN standards such as categories of safety related parts of control systems, interlocking, guarding arrangements etc.

It was further noted that many of the key C-type EN standards, which cover particular types/classes of machinery, were in provisional format during the period of study. This has caused confusion among suppliers due to the fact that they were unaware of the status of provisional (pr) EN standards. Provisional EN standards must be utilised during the design and construction stage and referenced on the declaration certificates, due to the fact that they represent current state of the art. As a result of this confusion, pr standards are not being utilised and referenced by many suppliers.

These observations were confirmed by the root cause analysis, which revealed that 42.3 per cent of suppliers assumed incorrectly that pr EN standards do not apply because they are provisional.

Secondly, the root cause analysis indicated that 69.2 per cent of those canvassed had received insufficient training on the structure and content of the EN standards. Without the necessary training it would be impossible to correctly cite and implement all of the relevant standards on the declaration certificates.

The above findings are in stark contrast to the findings of the report commissioned by the DTI, discussed in Chapter 2, which confirmed that over 90 per cent of machinery exporters comply with the EU Machinery Directive and that over 58 per cent feel they fully comply (DTI, 1998).

6.2 Risk Assessment

The research findings revealed that only three suppliers (11.5 per cent) had undertaken a risk assessment, where applicable. However, only two (7.7 per cent) were adjudged to be in accordance with the requirements of EN 1050. The reasons why the remaining risk assessment was considered inadequate was that it failed to evaluate risks in a structured and systematic manner. In addition, it did not consider all of the risks throughout the complete life cycle of the machine (design conception through to decommissioning/disposal).

The root cause analysis revealed 92.3 per cent of suppliers were unaware of the requirement that risk assessment should encompass the life cycle of the machine. In addition, 88.5 per cent either did not, or could not provide a risk assessment. It was noted that the reasons for this non-conformance is the lack of adequate training. This was confirmed by the root cause analysis which revealed that 80.8 per cent had received either no or inadequate training on machinery risk assessment and 69.2 per cent of suppliers had received either no, or inadequate training in legislative requirements and standards.

6.3 Implementation Of Risk Assessment Standards

The semi-structured interviews revealed that 84.6 per cent could not demonstrate the specific requirements of the risk assessment standard EN 1050, as well as other

EN standards that require a risk assessment to be undertaken. These included EN 292-1, EN 954-1 and EN 1088.

While it is possible to note that the reasons for this non-conformance is that 80.8 per cent of suppliers had either received no or inadequate training on machinery risk assessment and 69.2 per cent had received either no, or inadequate training in the EN standards. Confusion is being caused by the multiplicity of risk assessment techniques contained within the EN standards. In addition the EN standards do not provide an informative annex, such as EN 415, to indicate how the techniques are linked to the framework. Also, none of the risk assessment EN standards indicate how risks are estimated and evaluated in a structured and systematic manner.

Risk assessment techniques are included in the following EN standards: -

1. EN 1050 provides a general overview framework for undertaking risk assessment.
2. EN 292-1 indicates a risk assessment technique, which is based on a flow chart and is called a "schematic representation of the strategy for selecting designed in safety measures".
3. EN 954-1 indicates a technique known as "event tree" analysis for selecting the correct category of safety related parts of control systems.

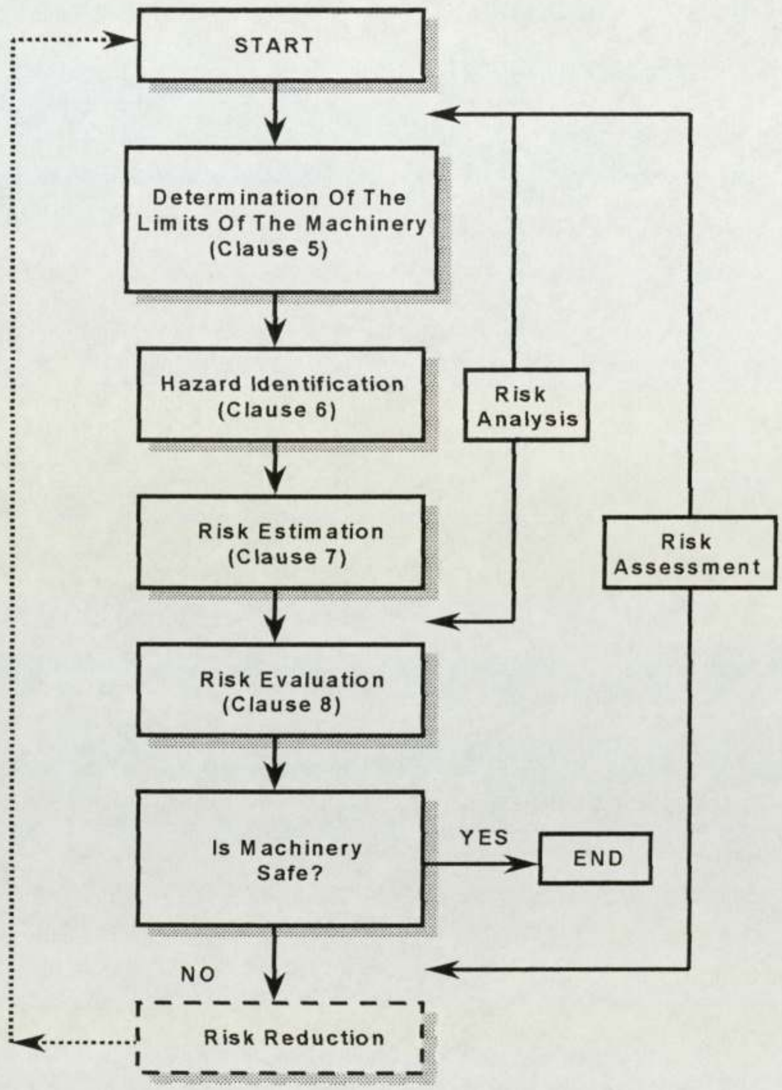
4. EN 1088 provides two flow charts in order to select the most appropriate interlocking devices. The one flow chart considers both control and power system interlocking. The other looks at interlocking devices with and without guard locking.
5. EN 201 is an example of all of the C type fluid power standards, which indicate the type of interlocking arrangements, which are compatible with the level of risk identified.

6.3.1 EN 1050 - Principles Of Risk Assessment

This is an A type standard that deals with principles for risk assessment. A simplified framework for risk assessment is illustrated in this standard and is shown in Figure 6.1.

An analysis of EN 1050 reveals that no specific guidance is given for the estimation and evaluation of risk. The standard does however contain a comprehensive checklist of hazards, which runs into 6 pages. In addition it contains an informative annex, which describes some hazard analysis techniques, such as preliminary hazard analysis and fault tree analysis.

Figure 6.1 Risk Assessment Framework (EN 1050:1997)



The main advantage of the comprehensive checklist is to guide the designer through the range and types of hazards that should be covered by the risk assessment. These include elements of the EHSRs. The disadvantages of the use of a checklist are that it is passive and blinkered.

One of the major shortcomings of the risk assessment methodology described in EN 1050 is that it is 'hazard-driven' and the informative risk assessment techniques do not include task analysis or human reliability analysis. As a result, designers who have used this framework did not appear to have included foreseeable misuse or types of human error in their risk analysis.

Raafat (1996) concluded that it is important to distinguish between continuing hazards, (those inherent in the work activity under normal operating conditions) and those hazards, which can result from hardware and software failure as well as those from foreseeable human error.

The approach adopted by the proposed American National Standard ANSI-B11 (2000) offers more practical guidance to machine designers on the application of risk assessment. The Technical Report TR-3 is for guidance only; it is not a machinery safety standard.

Unlike EN1050, this guide focuses attention on foreseeable tasks and activities associated with the machine through out its life cycle. It recommends the application of a task-based approach to risk assessment, and recognises the partnership between suppliers and users of machinery in the identification of relevant task, and the role of users in controlling residual risks. TR-3 also gives practical guidance on the evaluation of risks, something that was omitted from

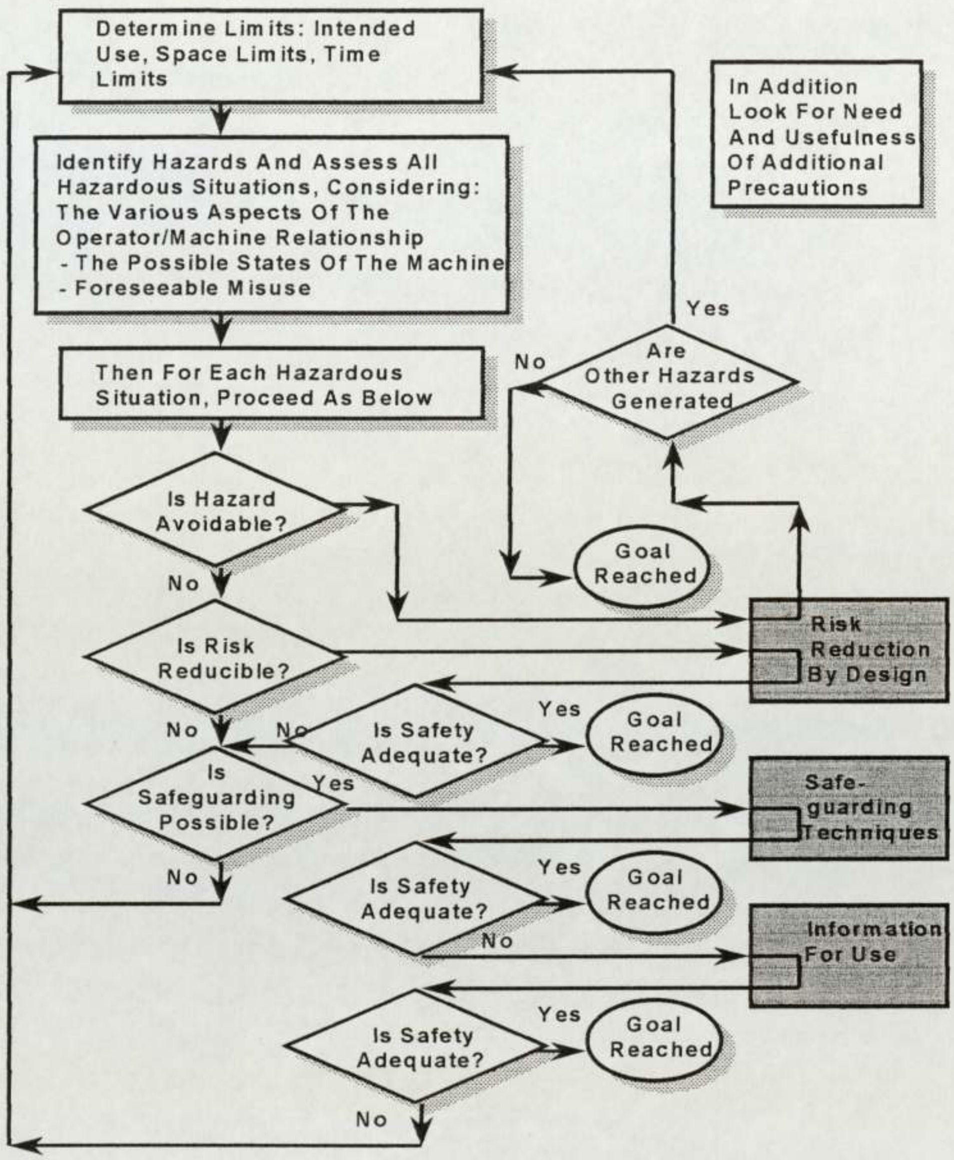
EN1050. EN 1050 was cited on the declaration certificates in only 5.7 per cent of instances.

6.3.2 EN 292-1 - General Design Principles

EN 292-1 provides a schematic representation of the strategy for selecting designed-in safety measures (Figure 6.2). This can be summarised as follows: -

1. To define intended and foreseeable uses for the machine, including installation/commissioning, use and maintenance through to decommissioning and disposal.
2. To assess all hazardous situations in the various states of the machine.
3. For each identified hazard and hazardous situation, to consider sequentially the following until the ultimate goal of safety has been achieved: -
    A. Is hazard avoidable? (Hazard elimination through design).
    B. Is risk reducible? (Risk reduction through design).
    C. Is safeguarding possible? (Safeguarding techniques).
    D. Is safety adequate? (Instructions, safe systems, warning etc.).

Figure 6.2 Strategy For Selecting Designed In Safety Measures (EN 292-1:1991)



The analysis has revealed that the two major criticisms of EN 292-1 are that it does not define how in reality safety can be deemed to be adequate, and it does not estimate and evaluate risks in a structured and systematic manner. Consequently it would be impossible to select the most appropriate safeguard, which must be compatible with the level of risk identified.

EN 292-1 was shown to be the most frequently cited of the EN standards (55.7 per cent). However in reality the hierarchy of risk control measures adopted by the designer/supplier did not conform to the procedures outlined in EN 292-1 on 76.9 per cent of machines e.g. risk reduction by design etc. In effect the suppliers of the machines were relying on the employer (end user) to ensure adequate levels of safety through the use of procedures.

The root cause analysis revealed that 88.5 per cent of suppliers were unaware of the requirement that the design of the machine should accommodate foreseeable misuse. In addition 80.8 per cent were unaware of the relevant EHSRs, which applied to their machines.

In one notable instance SP Engineering, No 15, who supplied a curing oven, had failed to design any facility for scrap removal from the 'deflash area'. Consequently operators were exposed to large numbers of hazards, such as high temperature components, highly repetitive actions etc., when removing scrap. Some form of automatic scrap removal would have eliminated and/or significantly reduced exposure to the hazards concerned. In another instance Uniloy, No 14, had failed to provide disconnection points outside of the hazardous area of the platens (moulds), on a 35 tonne closing capacity injection moulding machine.

6.3.3 EN 954-1 - Categories Of Safety Related Parts Of Control Systems

This is a Type B2 standard, which relates to the general principles for the design of safety-related parts of the machine control system. The inspection of documentation section revealed that this key standard was one of the least understood.

A control system is a system, which responds to input signals and which in turn generates output signals, which allows the machinery to perform controlled functions.

The input signals may be made by the operator (manual control), or automatically controlled by the equipment through sensors or protection devices, e.g. guard interlocking devices, photoelectric device, emergency stoop or speed limiters.

The objective of EN 954-1 is to prevent or reduce the likelihood that a failure in the safety device, wiring, contactors, hardware, and software could cause injury or ill health.

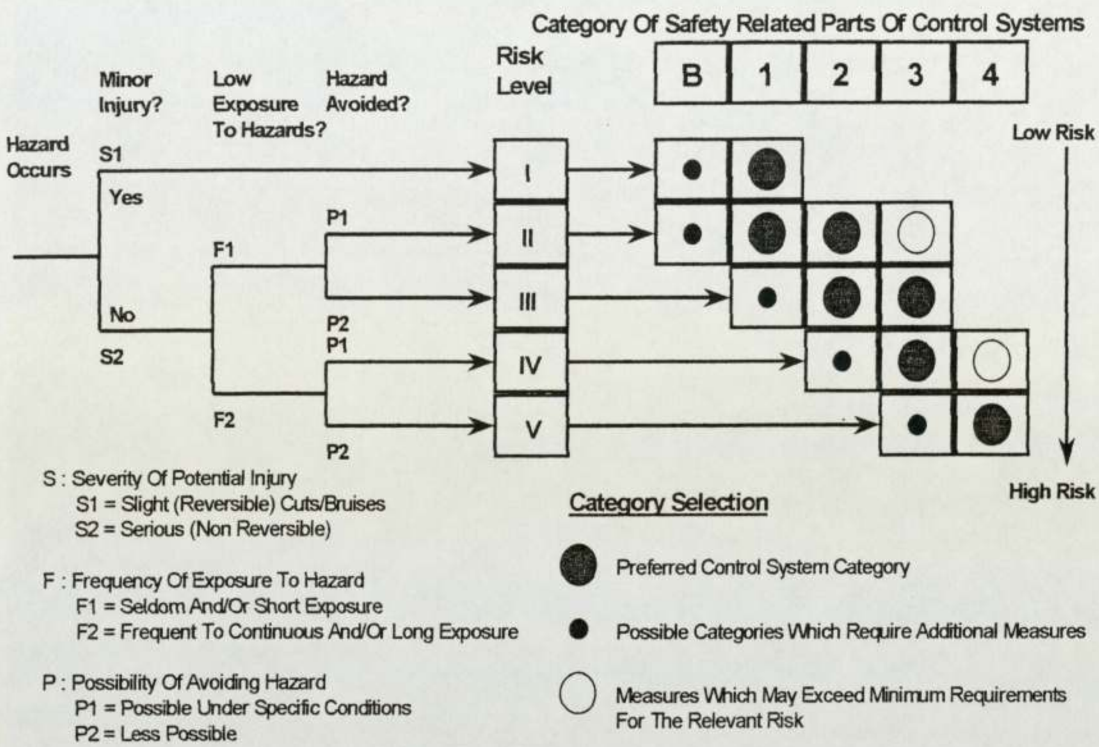
The subject of control systems generally and the safety related functions of control systems in particular are complex. The harmonised standard EN 954-1 provides guidance for the design and categories of control systems, based on risk assessment.

The complexity of this subject is further compounded by the use of programmable electronic systems in the machine control system. Guidance on the use of programmable electronic systems for safety related applications are not specifically covered by existing EU harmonised standards, however, the International Electro-technical standard IEC 61508 (1999) is generally used to identify, through a process of risk assessment, the relevant Safety Integrity Level (SIL) required for the control system.

EN 954-1 uses risk assessment with the sole objective of selecting the appropriate level of integrity (category) of the control system, based on Event Tree Analysis. The semi-structured interviews revealed that many machine designers believed that this was the only type of risk assessment needed to demonstrate compliance with EHSRs.

Figure 6.3 illustrates the use of event tree methodology for the selection of categories of safety related parts of the control system according to EN 954-1. The standard describes each of the four categories in terms of objectives to be met and system behaviour. Category 1 is used for low risk, where one failure in the control system can result in a minor injury, whilst category 4 represents the highest level of integrity, where accumulation of faults in the control system would not lead to potential injury. There are however many drawbacks associated with this subjective criteria for selection.

Figure 6.3 Assessment Of Risk According To EN 954-1:1996



These include the following: -

1. The event tree always assumes that minor injury would result in low risk. This is strictly incorrect as risk also involves the likelihood of the hazard being realised.
2. The selection criteria for control systems categories for risk levels II and III is unclear.
3. This methodology ignores the expected frequency of a fault in the control system (initiating event), as the control system reliability would have a significant impact on the selection process, based on quantified risk.

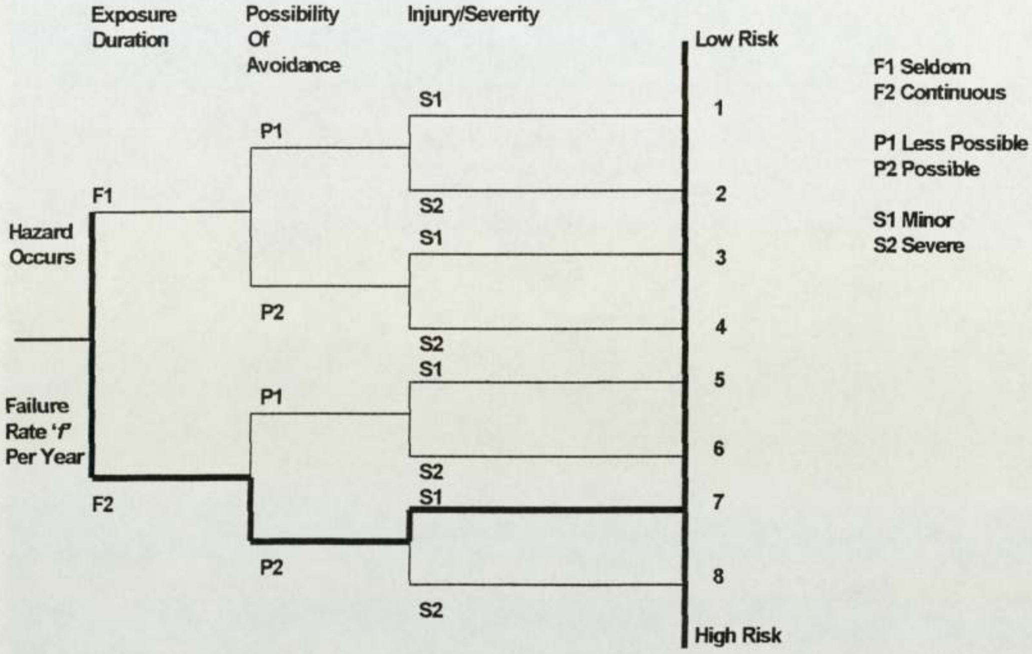
4. The logical sequence of events represented in Figure 6.3 is incorrect. This should be reversed.

A completely different selection criterion would result from the correct application of the event tree analysis. If, for example, a person gains access between the platens of a press, the initiating event in an event tree analysis would be a fault in the control system that could result in the inadvertent closure of the platen, thereby causing a crushing injury.

The logical sequence of events, following the initiating event is the presence of an individual between the platens (danger zone). The next event would be the possibility of avoiding injury, which is a function of speed of movement of the platen and proximity of individuals. The last event would relate to severity of potential injury.

Figure 6.4 illustrates the correct construction of the event tree. The logical sequence of events identifies eight possible end scenarios. It can be seen that minor injury may result in high risk (scenario number 7), if an individual is exposed to the hazard for an extended duration and cannot avoid injury, due to the high-speed movement of the machinery part.

Figure 6.4 Properly Constructed Event Tree



If however, the expected frequency of all faults in the control system was extremely small, then Individual Risk of fatality would be calculated as: -

Individual Risk = 1×10^{-6} per person per year or less.

This level of risk is regarded in the UK as broadly acceptable and no further risk reduction measures are necessary. This type of risk calculation is known as quantified risk assessment. Event tree analysis is a recognised technique for the quantification of risk.

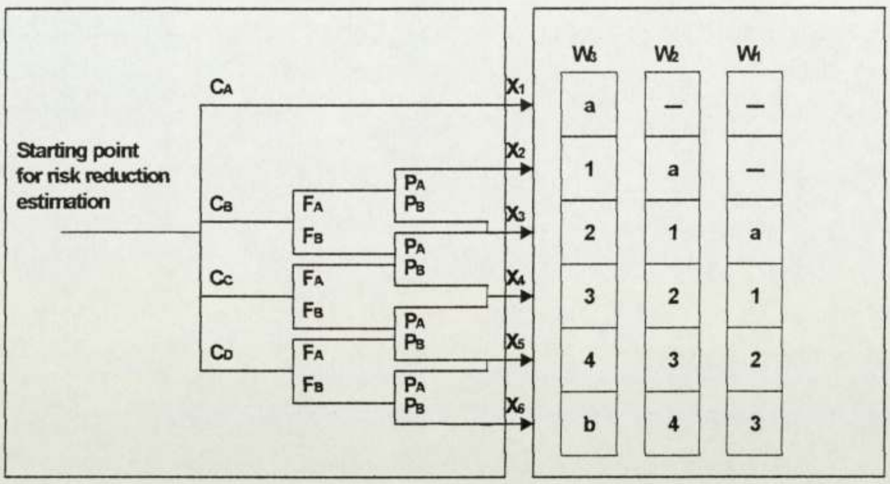
The use of quantified reliability data was considered in the risk assessment methodology adopted by IEC 61508 (1999). Figure 6.5 shows a general scheme for the risk assessment methodology used by IEC 61508- part 5. This standard identifies four safety integrity levels (SIL's) for the electrical/electronic programmable electronic safety-related systems.

It appears that there was an attempt to align IEC 615008 with EN 954-1 in terms of safety integrity levels. Both standards use event tree analysis for the selection of the appropriate category of control system, and both standards have made the assumption that minor injury should be regarded as low risk. The event tree analysis used in Figure 6.5 uses the same out of sequence events, similar to that used by EN 954-1, but has added two more categories of injury severity.

IEC 61508 however, added a third dimension to the event tree analysis in the form of probability of the unwanted occurrence (W): W1 is low and W3 is relatively high. This probability influences the selection of SIL according to each scenario. However, the frequency of the initiating event is not considered, which makes this assessment somewhat subjective.

IEC 61508-5 explores different criteria for risk tolerability, based on the UK three tier 'ALARP' concept and the use of a semi-quantitative risk matrix.

Table 6.5 Risk Graph According To IEC 61508-5



C = Consequence risk parameter

F = Frequency and Exposure risk parameter

P = Possibility of failing to avoid risk parameter

W= Probability of unwanted occurrence

— = No safety requirement

A = No special safety requirement

B = A single E/E/PES is sufficient

1, 2,
3, 4 = Safety Integrity Level

The use of event tree analysis may be inappropriate for the evaluation of risks in the way it has been used in EN 954-1. This is largely due to the nature of binary logic, things either happen or don't, e.g. success and a failure. Both are mutually exclusive. This concept cannot be applied to describe the severity of injury and ill health, or to the proportion of time an individual is exposed to machinery hazards. There are a number of tools developed, based on semi-quantitative methods for the evaluation of risks, which may be better suited for the task of selecting the most appropriate category or safety integrity level, e.g. the risk calculator, Raafat (1996). The risk calculator will be discussed in more detail later in this Chapter.

In 88.5 per cent of instances the inspected items of machinery had the incorrect category of control system integrity. The 23 items that were adjudged by the analysts to have the incorrect category of control system had all been fitted with a category '2' system or less, which meant that the 'safety function could be lost between monitoring checks'. This was an unsatisfactory outcome and one, which was not compatible with the level of risk identified on the machinery.

It would appear that where the standard had been referenced, an incorrect conclusion had been drawn from the 'event tree' type risk assessment contained within. Where suppliers had not referenced the standard then it became apparent that the control system integrity had been selected on a superficial basis and not through the application of risk assessment.

6.3.4 EN 1088 - Interlocking Devices Associated With Guards

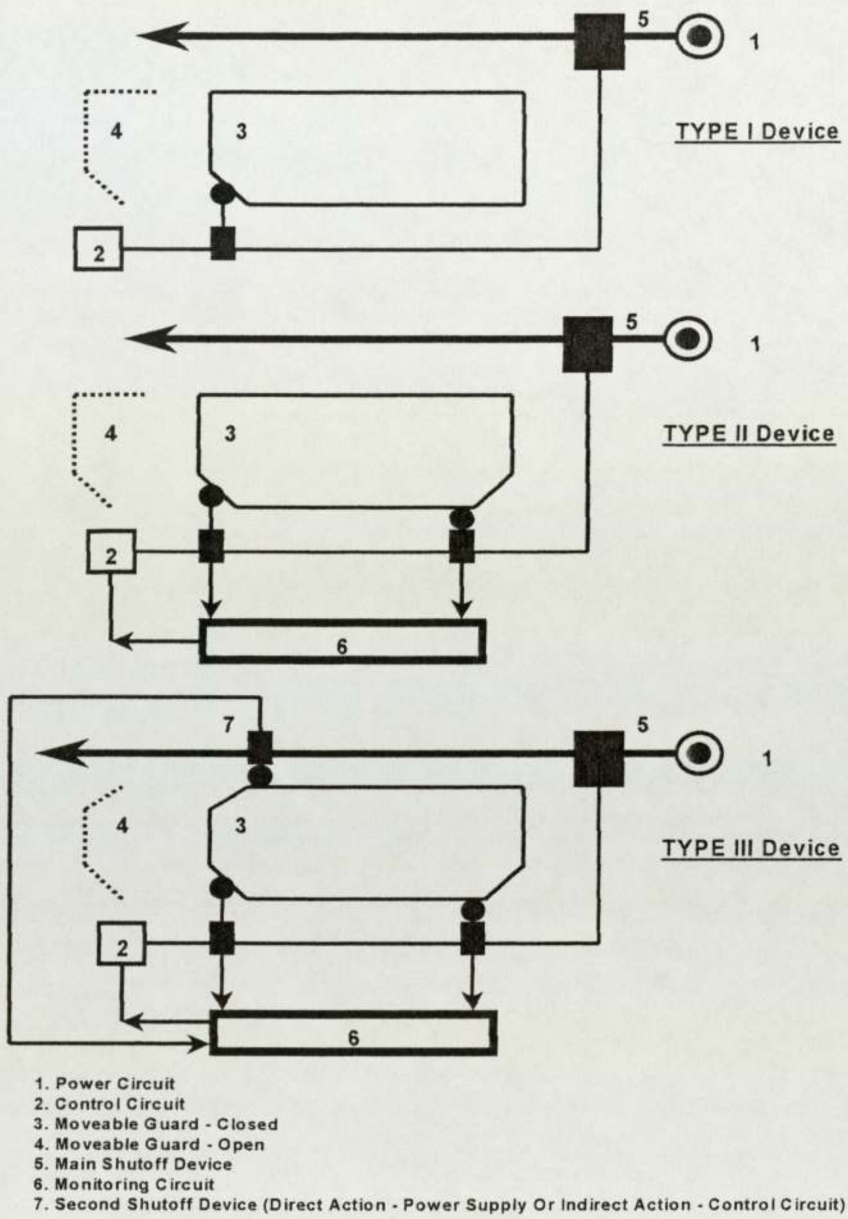
EN 1088 provides two flow charts for selecting interlocking devices. The first flow chart is linked to an explanation of both control and power system interlocking. For example, in control system interlocking, the energy supply to the machine actuators or mechanical disconnection of moving parts from the actuators is triggered by the control system. This is commonly known as indirect disconnection. Alternatively the machine designer/supplier can install a power system interlocking system that directly interrupts the power supply by direct disconnection (Nicholas 2000b).

The second flow chart indicates a requirement for interlocking devices with and without guard locking. For example in guard locking it would be impossible to open the guard until a fixed time has elapsed or zero-speed detection has been realised, thereby preventing personnel from coming into contact with hazardous parts of the machine (Nicholas 2000b).

The analysis of EN 1088 has shown that no indication is made as to how the two flow charts relate to the level of risk identified. In addition EN 1088 indicates a requirement to undertake a risk assessment in line with EN 1050. Given the fact that the risk assessment standard does not evaluate risks in a structured and systematic manner, this also would be of no assistance to designer/suppliers in selecting the most appropriate interlocking devices.

Further analysis of the interlocking standard reveals that no practical guidance exists on the configuration of the various types of protection devices. The standard only considers the different variety of safety sensors and whether they should be wired through the control system or linked directly to the power system. In order to obtain guidance on the three 'types' of interlocking configuration it is necessary to access one of the fluid power C-type EN standards, such as EN 201. The fluid power standards (C-type only) provide diagrammatic detail of the three different types of interlocking configuration for protection devices (Figure 6.6).

Figure 6.6 Protection Devices Types I, II, And III



They include the following: -

1. Protection device type I (low risk) - moveable interlocked guard with one position switch acting on the main shut-off device of the power circuit via the control circuit.

2. Protection device type II (medium risk) - moveable interlocked guard with two position switches both acting on the main shut-off device of the power circuit via the control circuit. The correct functioning of the two position switches shall be monitored at least once during each movement cycle of the guard. A fault in any of the switches shall be recognised and the commencement of any further dangerous movement of the machine shall be prevented.

3. Protection device type III (high risk) - Moveable interlocked guard with two separate interlocking devices both independent of one another. One device shall act in accordance with protection device type II. The other shall act directly or indirectly on the power circuit using a position detector. The correct functioning of the two separate interlocking systems shall be monitored at least once during each movement cycle of the guard. Any fault shall be recognised automatically and the commencement of any further dangerous movement of the machine prevented.

It was noted that 80 per cent of machines had interlocking arrangements, which were incompatible with the level of risk identified, and were not in accordance with the requirements of EN 1088.

It was apparent that the type of interlocking arrangements fitted to the machinery had been selected on a superficial basis and had not been selected through the application of a structured and systematic risk assessment and knowledge of the different types of configuration.

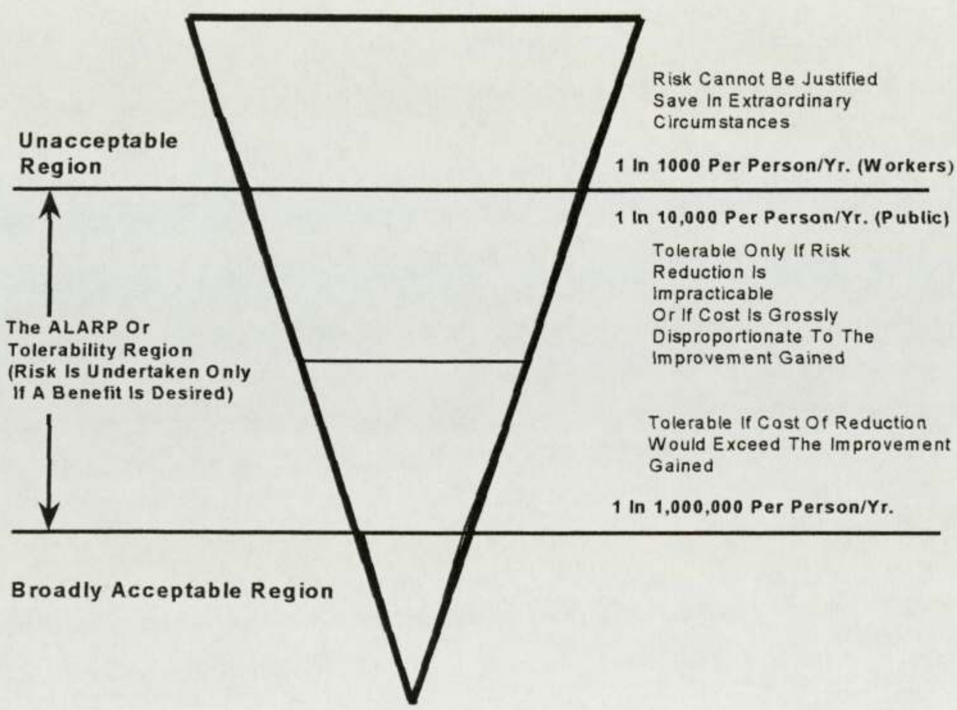
6.3.5 Estimation And Evaluation Of Risk

One of the main criticisms/weaknesses of the harmonised EN standards is that no guidance is given for the estimation and evaluation of risks. Estimation or measurement of the risk is of vital importance if the risk is to be evaluated fully. Risk evaluation determines the tolerability of risk. It is dependant on the methodology utilised and can be described qualitatively, semi quantitatively and quantitatively: -

1. Qualitative Risks - No figures, only judgment is used to estimate the risk level. For example, the chance of a major injury to a maintenance technician could be described as high, medium or low.
2. Semi Quantitative Risks - These may be ranked on a numerical scale from 1 (low risk) to 25 (high risk).
3. Quantified Risks - Risks may be described as a frequency or probability in absolute terms. For example a risk of a fatality may be described as 1 in 1000/year. The quantification of risk requires accurate statistics and is normally only utilised in major hazard situations e.g. fire/explosion etc.

The most widely used criteria in the UK for the evaluation of quantified risks is the Health and Safety Executive 'Tolerability of risk from nuclear power stations - 1992', from which Figure 6.7 is taken. This criterion sets the limit for maximum tolerable risk of a fatal accident to a worker in a hazardous industry as 1 in 1000 per person per year, and the maximum tolerable level of risk to a member of the public as 1 in 10,000 per person/yr.

Figure 6.7 UK Criteria For The Tolerability Of Risk



The level of acceptable risk is considered to be 1 in 1 million per person per year. The HSE criteria refer largely with fatal accidents, but stipulate that all risks should be reduced to a level 'As Low As Reasonably Practicable' or 'ALARP'.

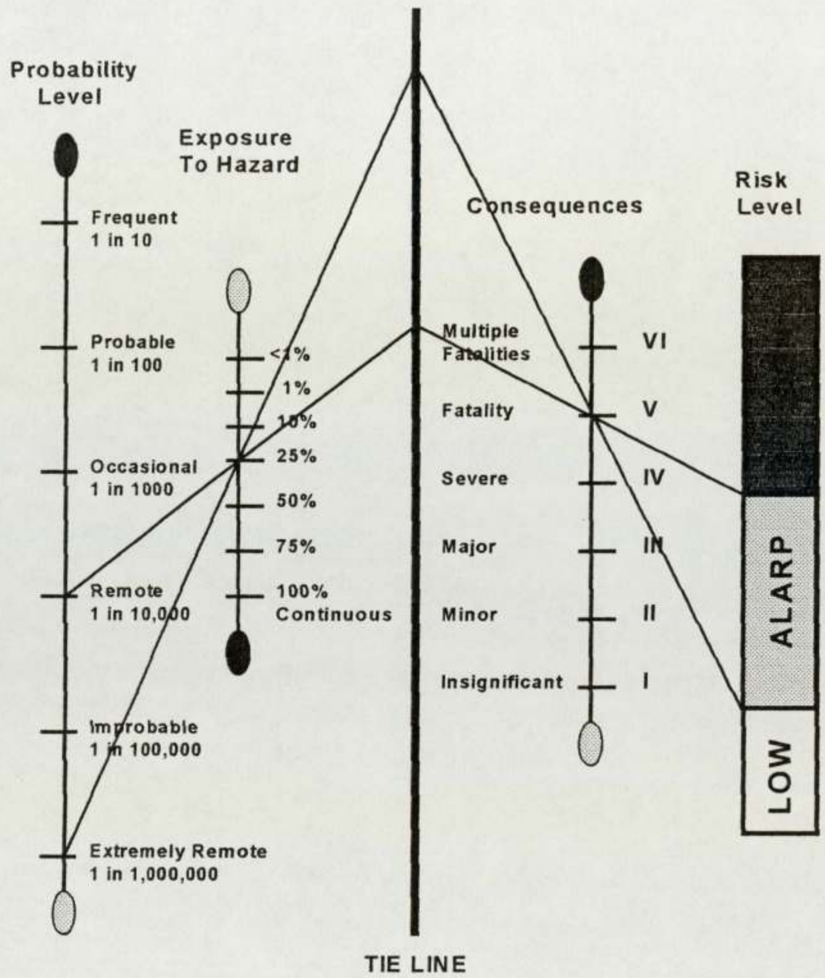
Other criterion for risk evaluation include the cost-benefit analysis or it may be possible to compare the level of risk with existing situations for similar activities or indeed to set organisational specific targets.

There are several drawbacks with many of the qualitative/semi-quantitative techniques for the estimation and evaluation of risks, as they miss out a vital component in measuring risk. This is the proportion of time person(s) are exposed to the hazard.

The risk calculator (Raafat, 1996) shown in Figure 6.8 was developed to provide a tool for rapid screening of risks in order to focus attention on risk levels, which are intolerable. It is important to note however that the risk calculator does not pretend to be entirely accurate. The main objective of its development is the ranking of risks rather than to provide a criterion for risk acceptability/tolerability.

Figure 6.8 The Risk Calculator (Source: Raafat 1996)

Consequence:	I	II	III	IV	V	VI
Personnel	Insignificant	Minor	Major	Severe	Fatality	Multi-Fatalities
Economic	<£1000	<£10,000	<£100,000	<£1,000,000	>£1,000,000	Total Loss
Environment	Minor	Short Term Damage	Major	Severe	Widespread Damage	Catastrophe



The risk calculator is a tool utilised for the screening of risks resulting from work machinery and equipment. The risk calculator is intended as a rapid guide to evaluation of the level of risks, in order to decide which risks would warrant a more detailed risk assessment.

One of the main differences between this risk calculator and other risk matrices is that the calculator takes into account the frequency and duration of exposure to a hazard. The risk calculator is primarily based on a nomogram introduced in the BS 5304.

The basic elements in calculating the order of magnitude of risk are: -

1. The chance or the likelihood that a hazard occurs ('annual probability level') - this ranges from frequent, or 1 in 10, to extremely remote, 1 in 1 million. The probabilities are used to describe the order of magnitude of what is meant by probable, remote…etc.
2. The frequency and duration of exposure to the hazard - this is measured on a scale ranging from very rare, or less than 1%, to continuous exposure 100% of the time.
3. The consequences or potential severity of injury/damage measured on a scale ranging from category (I) minor injury/ill health, to category (VI) multiple fatalities.

By connecting the appropriate points on each scale and using the tie line in the middle of the calculator, it is possible to determine the level of risk involved. The risk level is divided into four general categories: -

1. High Risk [A] - which indicates that the level of risk is unacceptable and cannot be justified on any grounds, or type III protection device (EN 1088) should be applied.

2. Medium Risk [B] - which indicates that the level of risk should be reduced to a level as low as is reasonably practicable 'ALARP', or type II protection device applies.
3. Low Risk [C] - which indicated that the level of risk is broadly acceptable and no further precautions would be necessary or protection type I applies.

If the level of risk falls between high and low, it has to be reduced to the lowest practicable level, bearing in mind the benefits flowing from its acceptance and the cost of any further reduction.

Given that the HSE criteria for tolerability of risk relates to Individual Risk (IR). IR refers to a named individual who is exposed to hazards during work activities. IR is usually obtained using the following formula: -

IR = Chance of a hazard being realised x Proportion of time exposed to the hazard x Probability the exposure will result in death.

Societal risk on the other hand refers to exposure of any person or persons to the hazard, and is normally used to describe the risk associated with multiple injuries/fatalities. The duration of exposure in some cases could be continuous or 100%, e.g. several personnel working 3 different shifts per day.

The risk calculator was calibrated using HSE's ALARP criteria in relation to IR as follows: -

1. If the hazard is present 100% of the time at work, and if an employee works 8hrs/day and 5 days a week, the proportion of time exposed to the hazard is approximately 25%.
2. If the annual chance of the hazard being realised in 1 in 10,000 per year, e.g. explosion and it was assumed that the employee is certain to be killed if exposed, then this should correspond with the maximum tolerable level of risk (top of risk level B) as shown in the risk calculator.
3. If the chance of the hazard being realised were on the other hand 1 in million per year, then this would represent the limit of 'broadly acceptable' risk (top of risk level C).

The area between risk levels A and C represents the 'ALARP' region. The risk calculator was calibrated using the above criteria.

The global impact of risk assessment on machinery safety standards is clearly gaining momentum. The role of risk assessment within the EN standards is fundamental in guiding the designer through hazard analysis and evaluation of risks, in order that they can select appropriate levels of integrity of health and safety measures. However, the number of ways in which risk assessment is described in different EN standards can result in confusion.

6.4 Implementation Of Other Key EN Standards

6.4.1 EN 294 And EN349 - Safety Distances And Minimum Gaps

Eighty four per cent of machines had guards and protection devices fitted which did not conform to the requirements of EN 294 (safety distances) and EN 349 (minimum gaps).

In one such instance where the safety distances (EN 294) were inadequate was on an aluminium filter press, supplied by Netzsch No 63. A 'photo electric' device had been fitted to the machine in order to prevent access to the hazardous parts of the press. However the 'photo electric' device had been fitted too close to the machine. Consequently it was possible to reach over and under the safety device and touch hazardous parts of the press.

In another instance a rubber-joining machine that had been supplied by Normec No 3 did not comply with the requirements for minimum gaps (EN349). A guard fitted around a 'taping' mechanism was fitted too close to an operating 'control pod'. Consequently it resulted in an operator's head being crushed between the guard and the pod during the commissioning of the machine. This resulted in a severe injury to the operator.

6.4.2 EN 953 - Machinery Guarding

It was noted that 57.7 per cent of machinery had been fitted with guards, which did not comply with the requirements of EN 953. Guarding deficiencies included: -

1. Not being of a robust construction.
2. Inadequate fixing arrangements e.g. hand removed spring clips used to secure to machine.
3. Giving rise to additional risks e.g. causing additional crushing/shearing hazards on moving machinery.
4. Easy to bypass/render non-operational.
5. Did not prevent ejected articles from being thrown outside the confines of the machine.
6. Causing excessive obstruction e.g. not being able to view the production process (Nicholas 2000b).

In one such instance Netzsch No 63 had provided a 'photo electric' device where there was a distinct possibility of being splashed by molten aluminium.

6.4.3 EN 418 - Emergency Stops

In 88.5 per cent of instances the machinery, where appropriate, had emergency stops fitted, which did not conform to the requirements of EN 418. This EN standard indicates a requirement that the re-setting of a control device is only possible as a direct result of a manual action on the control circuit itself, after the emergency stop has been activated. Upon examination of the non-conforming machines it was evident that power was restored to the machines when the emergency stops were re-set. In effect they did not require the manual switching of the control circuitry to re-set the machine. Consequently, it was possible for operators/maintenance personnel to be exposed to unacceptable hazards/hazardous situations.

Further analysis also revealed that the emergency stops had been wired through the Programmable Electronic System (PES). Consequently it was possible to override the 'E' stop functions, which was clearly a totally unacceptable outcome. There is clearly an inter-relationship between this standard and EN 954-1. It was identified that the integrity of the 'E' stop function could be lost between monitoring checks of the control system.

6.4.4 EN 982 And EN 983 - Fluid Power Systems

In 88.8 per cent of instances suppliers had failed to ensure, where appropriate, that their machines conformed to the requirements of EN 982 (hydraulics) and EN 983 (pneumatics). In all instances there was a failure to consider the requirement to prevent 'gravity fall', due to a failure/removal of the hydraulics/pneumatics power supply.

In one instance Centreline No 27, who supplied a large pneumatic rise and fall guard, had failed to fit a counterbalance valve into the pneumatic circuit. Consequently when the pneumatic power was disconnected from the system, the guard fell under gravity narrowly missing the machine operators.

6.4.5 EN 60204-1 - Electrical Equipment

There was a significantly lower occurrence of non-conformity with the electrical standard EN 60204-1 (44 per cent), than there was with other key EN standards (EN1050, EN 954-1 etc.). The reasons for this are that the electrical standard tends to confirm what electrical engineers have highlighted over the years as 'accepted best practice'. This includes for example, tried and tested components such as transformers for supplying controlled voltage, protection against earth faults, etc. It is also one of the best known of the EN standards.

Where the electrical standard interpretation failed, it tended to be in system configuration. For example, R&R Engineering No 1 and Netzsch No 63 had a main electrical panel 'live' even when it was switched off.

6.4.6 EN 50100, EN 574, And EN 999 - Trip Devices, Two Handed Controls And Approach Speeds

Further analysis revealed that 70.5 per cent of machinery had trip devices/two handed controls fitted which did not conform to the requirements of EN 50100, EN 999 and EN 574.

The trip devices (EN 50100 Electro-sensitive protection) had been fitted with a single photoelectric beam configuration, which was not compatible with the level of risk identified. Consequently it was possible to reach over and under the beam and not activate the trip mechanism. This was a totally unacceptable outcome due to the fact that it afforded little protection to the operator.

In addition it became evident that two-handed controls (EN 574) had been selected on a superficial basis and a lack of understanding on the role of risk assessment. All 12 machines had been fitted with the incorrect type of two-handed control and were subsequently incompatible with the level of risk identified. For example, a high risk-rating outcome should have a type III two handed control fitted, i.e. single fault tolerance and automatic cross monitoring.

Two hand devices must be designed so that the operator shall use both hands during the same time period (one hand on each control actuating device, to operate the controls). This must be a simultaneous action with no time lag between the initiations of each of the two control signals. The machines surveyed did not require a simultaneous operation of the two handed controls. These machines could have been operated one handed thereby creating significant risk to the operator.

It was also evident that suppliers had failed to reference EN 999, due to the fact that all of the non-conforming two handed controls had been fitted too close to a hazardous area e.g. a main crushing point. The correct application of EN 999 would ensure that the two handed controls are situated at a 'minimum distance' which is compatible with the approach speed of the operator. This would prevent an operator from coming into contact with hazardous parts of the machine, whilst it is in motion.

6.4.7 C-type Standards

Only 13.3 per cent of suppliers, where appropriate, had correctly implemented the applicable C-type standard. Those suppliers who had referenced EN 775, which is the C-type standard for 'industrial robotics', had failed to adequately control hazards via the machinery design.

EN 775 was converted from ISO's without conforming to the structure of the EN standards. The standard has been written in a way as to be incompatible with other C-type standards and in particular the risk based approach. For example, it only indicates some of the hazards associated with robotics applications; it is in no way a definitive document listing all of the hazards. In addition it does not recommend the type/category of protection devices to be fitted.

A C-type EN standard must have a risk assessment applied to it. This must indicate all of the hazards on the particular machine in question, the correct type of interlocking arrangement and category of safety related aspects of control systems etc., which must be compatible with the level of risk identified.

Other C-type standards had not been correctly implemented because they had either not been referenced and/or not referenced correctly due to an overall lack of understanding on the part of the designer/supplier.

The root cause analysis has revealed that the reasons for this non-conformance, in the implementation of key EN standards are fourfold. Firstly, 92.3 per cent of suppliers found the EN standards complicated and confusing.

Secondly, 84.6 per cent of suppliers concluded that the EN standards did not provide adequate guidance for designers.

Thirdly, 69.2 per cent of suppliers had received insufficient or no training in legislative requirements and standards. This was confirmed by the fact that over 76 per cent were unaware of the role of the European standards e.g.B1 and B2 and that over 57 per cent were unaware of the structure of the transposed harmonised standards.

Fourthly, in 26.9 per cent of instances, supplier management did not provide standards for designers.

6.5 Instructions, Safe Systems Of Work, Safe Access And Warnings

Additional analysis has revealed that 80.8 per cent of suppliers had failed to provide adequate/documented instructions for the commissioning stages. In all instances no consideration had been afforded to residual risk, due to, for example, the overriding of safety features/devices.

In addition 53.8 per cent of suppliers had failed to provide instructions for safe maintenance, cleaning, setting, adjusting etc. Specific details of what should be included in instructions, together with warnings of residual risks are indicated in 1.7 'indicators' section of the EHSRs.

It was also identified that safe systems of work were inadequate and had not been documented in 69.2 per cent of instances. Suppliers had failed to consider the following: -

1. Undertaking a task based assessment to identify who is involved, what is involved and where and how the tasks are going to be performed.
2. Clarify safe methods for authorisation and definition of responsibilities.

3. Clarify the planned sequence of events, detailed work methods, control of residual risks and precautions.

Machinery suppliers are required to demonstrate a hierarchy of risk control measures, which conform to the EHSRs. One such step is to provide protection from hazards by design thereby allowing for safe access into the machine for maintenance, setting, and faultfinding, adjusting and cleaning. In addition safe access must be provided for during the normal operation of the machine.

It was revealed that 80.8 per cent of machines did not have safe access for maintenance, setting, faultfinding etc. For example tool changing tasks that required personnel to enter a hazardous area. This could have been prevented through improved tool change design i.e. disconnection points outside the machine without the need to enter hazardous areas.

In addition 46.2 per cent of machinery did not have safe access for normal day-to-day operations. For example, by not having a system of automatic scrap removal operators were exposed to a wide diversity of hazards by having to constantly enter a hazardous area. Clearly more thought had been given to normal operations than to maintenance, setting, adjusting etc., however there is significant room for improvement.

Warning notices (indicating residual risk) were deficient in 65.4 per cent of instances. They failed to warn personnel of residual risk and in some instances were in a foreign language. One such example was with the aluminium filter press supplier Netzsch; they had posted all but one of their warning notices in German. The notice that had been posted in English warned that the electrical control panel was 'alive even when dead' (switched off). A machinery state, which clearly did not comply with the EHSRs.

The root cause analysis has revealed that 34.6 per cent of suppliers were unaware of the need to provide safety instructions for access into the machine for maintenance, setting, faultfinding etc.

Additional analysis of the root causation factors revealed that 65.4 per cent of suppliers were unaware that safe systems of work need to be documented for the installation and commissioning stages.

It is noted that the reason for this non-conformance was that 69.2 per cent had received either insufficient or no training in legislative requirements and standards.

6.6 Technical File

Only 11.5 per cent of suppliers demonstrated that some form of technical file existed for their machinery.

The root cause analysis confirmed that 84.6 per cent were unaware of the requirement for and content of a technical file.

The reason for this non-conformance is that 69.2 per cent of suppliers had received either insufficient or no training in legislative requirements.

6.7 Safe Machinery

Only 15.4 per cent of machines were adjudged by the analyst to be safe. Barnsley Cranes, No 41, provided a safe machine because that they had followed prescriptive and obsolete traditional British standards. These cannot be utilised to demonstrate compliance with the EU Machinery Directive and they therefore should not have affixed the CE mark.

In addition Barnsley Cranes had not undertaken a structured and systematic risk assessment for the complete life cycle of their product.

Only three suppliers had complied with the requirements of the EU Machinery Directive. These were ABB No 30, Van der Lande No 56 and Komatsu No 67.

The only criticism of Komatsu is that they failed to sign their declaration certificate. It is ironic that a Japanese supplier can demonstrate compliance with a EU requirement, where others from within the EU have failed abysmally. Komatsu received third party accreditation assistance from the Advanced Manufacturing Technical Research Institute (AMTRI), which is in Macclesfield in Cheshire. AMTRI is one of the DTI approved bodies for third party accreditation.

ABB had manufactured a machine that was deemed to be safe due to the fact that they had sought external consultancy assistance on how to comply with all aspects of the EU Machinery Directive.

Van der Lande had referenced and correctly applied EN 415, which is the ‘C’ Type EN standard for materials handling equipment. In addition they also had received external consultancy assistance.

Designers/suppliers were unaware of the legal position, if found not to comply with current legislative requirements and standards in 73.1 per cent of instances.

Additionally 61.5 per cent of suppliers saw compliance with the EU standards/documentation as a quality systems function completed after the manufacturing process and over 30 per cent assumed incorrectly that British standards could satisfy relevant EHSRs.

6.8 Summary Conclusion

Detailed analysis of the degree of compliance demonstrated by a sample of 26 machinery suppliers into the UK during stage 1 of this study, has shown widespread non-compliance with the EU requirements, particularly in relation to risk assessments, technical files and the application of correct EN harmonised standards.

The root-cause analysis carried out in this study identified the contributory factors for non-compliance of machinery suppliers with the EU Machinery Directive, as follows: -

1. Provisions of the EU Machinery Directive.
2. Application of the European machinery safety standards.
3. Issues relating to the suppliers management system.

The three main contributory factors in the first category, related to the role of risk assessment in compliance with the provisions of the EU Machinery Directive/SMSR. These include the lack of understanding and application of risk assessment.

The analytical results clearly indicated in the second category that there is wide spread confusion by most interviewees, about the complex structure and the non-prescriptive nature of the EN standards. Thirteen point three per cent of contributory causes within this category related to the lack of understanding of the specific requirements of EN 1050, particularly the hazard identification checklist. Other EN standards that require the application of risk assessment were not recognised by the same significant proportion of suppliers.

The most significant contributory causes in the third category were identified as inadequate/lack of training on risk assessment and inadequate/lack of training in the EU machinery safety legislation and standards.

Examination of the way risk assessment is represented by three key European standards has identified inaccuracy and several inconsistencies. This may have contributed to the high degree of confusion shown by machinery suppliers surveyed in this study.

The results from the empirical research findings support the proposed amendment to the EU Machinery Directive for a change to the Conformity Assessment Arrangements under Annex IV, which was discussed in Chapter 2. The proposal that an approved body must check the technical documentation to ensure that the European standards have been correctly applied is well justified. This should be seen as independent verification that would ensure a higher degree of compliance with the EU Machinery Directive.

In addition the research findings cast doubt on the accuracy of the DTI findings contained in Chapter 2. The DTI might have got better results if they had not used a telephone poll! The fact that they did not examine any documentation or machinery supplied, resulted in the inability to verify whether designers were being truthful in their responses. Clearly this research has demonstrated the DTI study was inaccurate.

The conclusions also support the research hypothesis put forward in Chapter 1.

The thesis will now move on to develop a model, which will demonstrate how safety can be integrated into machinery design.

Chapter 7: Integrating Safety Into Machinery Design

The purpose of this Chapter is to present a model which will assist machinery and system designers in integrating health and safety into the design process. The model will be underpinned by the adoption of a risk-based strategy.

7.1 Overview

This Chapter considers the integration of a health and safety model, utilising the principles of the generic model (aimed at capitalising on existing knowledge) presented by Harani 1997 and subsequently modified by Hasan, Bernard, Ciccotelli, Martin 2000 (Chapter 2).

It has recourse to the principle of Meta modelling and proposes a machine/system model that represents and groups all the information defining the product in the same knowledge base. This system model integrates the concept of risk assessment in order to assist the designer in integrating health and safety into the machine/system design.

The proposed model considers the mode of intervention of personnel within the system as a whole, the tasks undertaken by personnel and both the tools and materials used to ensure correct operation of the system.

The main concept of this model is to integrate health and safety during the machine design stage. The model will utilise the risk-based approach to machinery safety, which as we discovered earlier in this thesis was the cornerstone of the EU Machinery Directive. Consideration will also be afforded to the inclusion of the harmonised machinery safety standards (Nicholas and Raafat 2000).

7.2 Modelling Machinery/System Safety

The concept of integrating health and safety during the machine/system design is shown in Figure 7.1. The machine/system model is made up of subsystems, the foreseeable tasks involved, danger zones, hazards, hazardous events, modes of intervention and risk assessment. Exposure to work hazards may constitute a significant risk if the machine designers do not adequately consider all foreseeable needs for interventions (Nicholas and Raafat 2000).

The key attributes of the proposed machine/system health and safety model are as follows: -

Machine/System: This includes name, serial number, description, raw material and finished product. It is important to identify the machine boundary and interfaces with other systems.

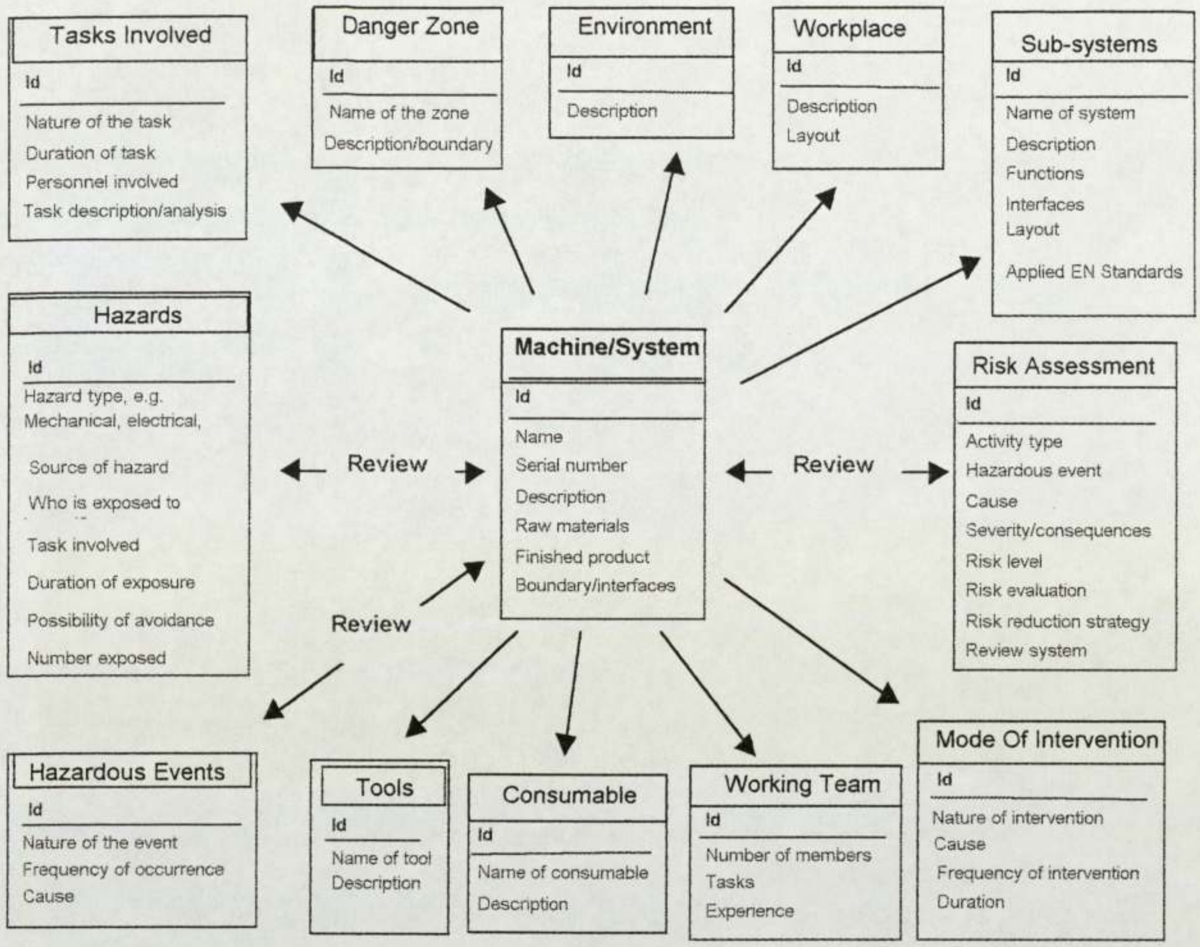


Figure 7.1 General Machinery/System Safety Model

Subsystem: This identifies parts of the machine, description, layout and functions. It is important within this description to identify relevant EU Directives and applicable transposed harmonised EN standards to each subsystem.

Mode Of Intervention: Represents machine–user interactions, i.e. the modes allowing access into danger zones to carry out foreseeable activities, e.g. tool setting, maintenance, faultfinding, programming, etc.

Working Team: This concept represents all those responsible for installing, operating, setting, maintaining, cleaning, repairing and faultfinding a machine (EN 292-1). It represents all those who are foreseeable at the design stage.

Danger Zone: Represents any zone inside and/or outside a machine whereby personnel are exposed to risk of injury or damage to health (EN 292-1), (EN 1050).

Hazards: Represents any source with the potential to cause harm. This will include the possibility of injury or damage to the health (EN 292-1) of the users during their activities inside the danger zone.

Hazardous Events: Represents one of the events liable to occur either accidentally or as a direct result of the working situation, caused by the users, the system or third parties. According to standard EN 1050 this concept is defined as an event likely to cause injury or damage.

Risk Assessment: Involves the probability (chance) of exposure to the harm inside the danger zone coupled with the consequences (severity) of exposure. It also considers evaluation of risk and whether corrective/preventive measures are required in order to reduce risks to a tolerable level.

Tools: This concept represents the tools that are utilised to ensure the correct operation of the system design.

Consumables: Represents the consumable materials that are required for the work activity.

Work Environment: This concept represents all the physical, chemical, biological, organisational, social and cultural elements that surround a working situation.

7.3 Concept Of Risk Assessment

Earlier in this thesis it was noted that the global impact of risk assessment on machinery safety standards is gaining momentum. The role of risk assessment within the European directives and harmonised standards is fundamental to the process of hazard analysis and evaluation of risks. In addition, it enables the designer to select appropriate levels of health and safety integrity (Nicholas and Raafat 2000).

Earlier in this thesis risk assessment was defined as a structured and systematic technique for identifying hazards, evaluating risks and prioritising actions in order that risks can either be eliminated or reduced to a tolerable level.

A general risk assessment framework (Raafat, 1996) is shown in Figure 7.2.

The main elements of risk assessment are: -

Define Machine/System: This should include description, intended use, space and time limits and boundaries/interfaces.

Identify Hazards: These include hazards and hazardous situations considering the various aspects of the operator-system relationship, the possible states of the machine and foreseeable misuse. Hazards can be classified as continuing hazards, which are inherent in the machine, material or substance; and hazardous events, which can result from machine/system failures (hardware/software) as well as potential human error.

Analyse Consequences: This primarily relates to the severity of injury and ill health as a result of exposure to the hazard. It can also be described in terms of economic losses due to interruption to production, asset damage and/or environmental damage/effects.

Estimate/Measure Risks: Risk is defined as the chance (probability) of the harm being realised combined with the consequences (severity). Risk therefore can be described in qualitative, semi-quantitative or quantified terms. For the vast majority of industrial machinery hazards, a semi-quantified measurement of risk is recommended.

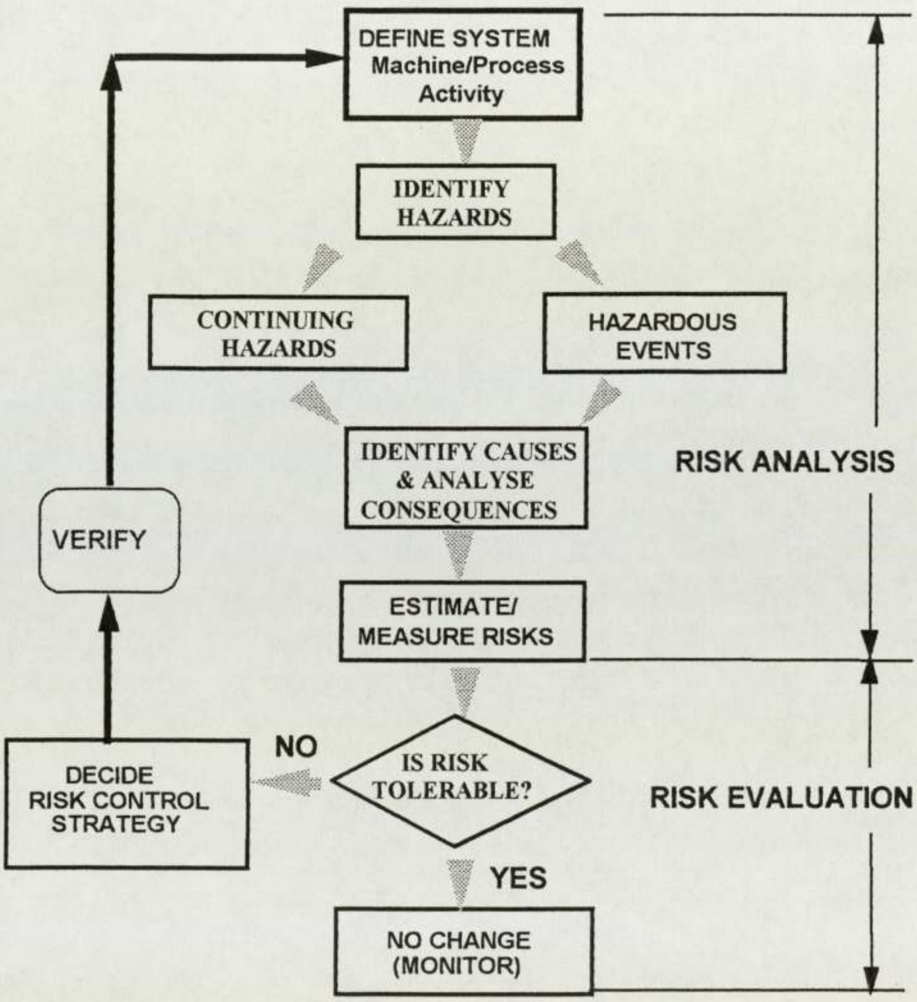


Figure 7.2 Risk Assessment Framework

Evaluation Of Risks: A criterion is selected to evaluate risks. That is to decide if the risks are tolerable or require some form of corrective or preventive measures.

Risk Control Strategy: If risks are adjudged to be intolerable, a hierarchy of risk reduction options are set out in the EHSRs (Chapter 3). They include the following: -

1. The first consideration is to design out hazards i.e. risk elimination via design.
2. Secondly, where this is not possible the risks should be reduced via the machinery design. The design should minimise the need for access into the danger zones and to accommodate foreseeable misuse.
3. The third option is to incorporate safeguards and safety devices.
4. The last option is to warn the user of any residual risks and to develop safe systems of work. This will possibly include the wearing of some form of personal protective equipment (PPE).

Verification: There will be a need to review the system following modifications, in order to ensure that these remedial measures will reduce risks to a tolerable level, and that no new hazards are generated as a result of design modifications.

7.4 Modelling Of Risk Assessment

Modelling of risk assessment (Figure 7.3) involves the following: -

Risk Assessment: This procedure represents the methodology to identify hazards associated with each danger zone or hazardous activity or both.

The two basic risk assessment techniques, which are considered more relevant to machinery safety, are the hazard-based approach (EN 1050, 1997) and the task-based approach (ANSI B.11-TR3, 2000). The task-based risk assessment is much more open-ended as it analyses different hazards associated with each step of the task/subtask (Nicholas and Raafat 2000).

The machine/system based risk assessment considers the following: -

Danger Zone: This identifies all hazardous areas inside and outside the machine by name, description of subsystems within each zone and boundary/interfaces with other danger zones.

Hazards: A list of hazards to be identified is presented by EN 1050. This includes for example mechanical, electrical, physio-chemical and hazards resulting from inadequate ergonomic consideration in the machine design.

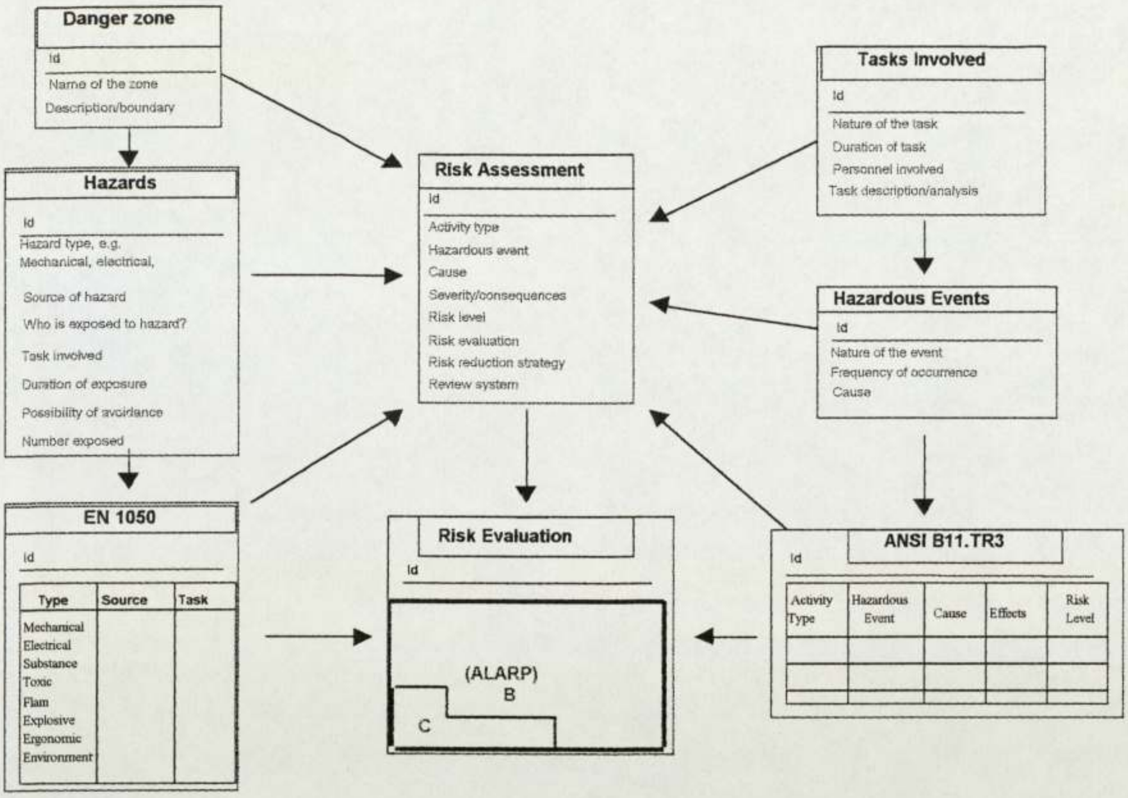


FIGURE 7. 3 Task-based Risk Assessment Model (© Nicholas 2000)

Tasks Involved: This identifies all foreseeable tasks, where an individual needs to enter a danger zone. These tasks must include normal operation and the different requirements for personnel intervention, such as maintenance, setting and faultfinding etc. This is important, as some safety measures may have to be overridden/defeated during for example installation and commissioning (which is foreseeable at the design stage).

It was discovered earlier in this thesis that task analysis is a very powerful technique for the designer to identify and analyse what needs to be done and when.

Hazardous Event: In this context, this attribute represents one of the events liable to occur on the system (like a technical malfunction), and how individuals may be exposed to harm. The approach adopted by ANSI B11-TR3 (ANSI, 2000), considers both the tasks involved and any potential hazardous events in a structured and systematic manner.

Risk Evaluation: It should be remembered that not every hazard and hazardous event would warrant risk reduction measures. It is only when the risk level is significant that the designer would consider a hierarchy of risk reduction options. There are a number of tools which have been developed, based on semi-quantitative methods for the evaluation of risks, which may be suited for the task of selecting the most appropriate category or safety integrity level, e.g. a risk matrix (ANSI, 2000) and the risk calculator (Raafat, 1996) discussed in the previous Chapter.

Evaluation of risks, using the approach adopted by (EN 1050, 1997) is based on the hazards identified in the danger zone, but the concept of risk evaluation is unclear. The task-based approach adopted by (ANSI, 2000) is more suited to the evaluation of risks associated with foreseeable modes of intervention, due to fact that it evaluates risk.

7.5 Application Of The Proposed Model

The example used to demonstrate the application of the model is based on a design of a mechanical 1200/800 tonne press line, used in the body shop of an automotive manufacturer. Five mechanical presses were imported from the Far East, which did not comply with the EU Machinery Directive. Due to the fact that the machinery suppliers were outside the EU and there was no UK agent, the automotive manufacturer was therefore deemed to be the importer (responsible person). Consequently they had to ensure that the machinery fulfilled the requirements of the EHSRs and was in fact safe before the CE mark could be affixed (Nicholas and Raafat 2000).

A new approach, utilising the model shown in Figure 7.1 was applied to the design of the motor vehicle body panel handling system, which was based on a single line flow. The new E-Line included, five single-action presses, two destack trolleys, seven six-axis robots, one tilt (centralising) table, two offload conveyors and ten die-carts. The general layout for E-Line is shown in Figure 7.4.

The Company operates a three-shift system, and the core working team consists of eight dedicated personnel per shift. Maintenance was introduced as part of the production schedule, so multi-tasking and cross functioning were essential elements of personnel training in order to provide increased flexibility.

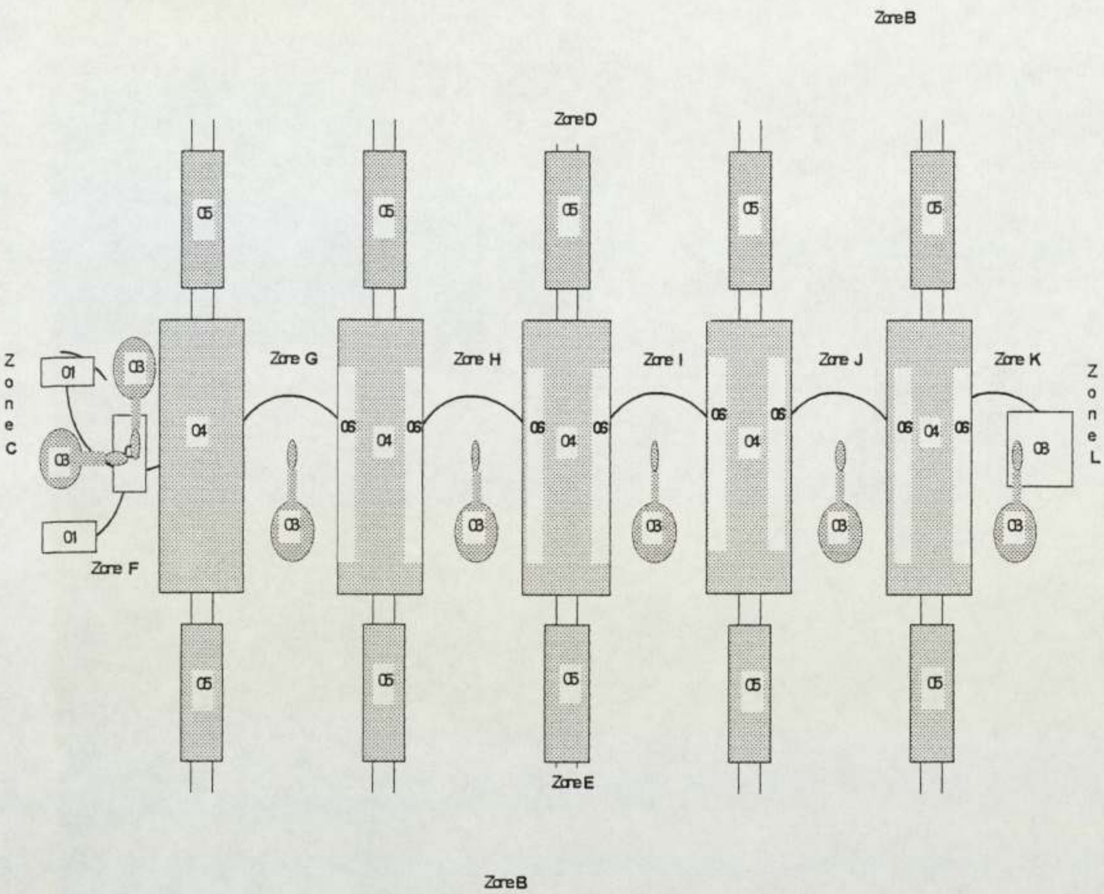


Figure 7.4 General Layout Of E-Line

The line operation starts by loading panels onto the destack trolleys, using fork-lift trucks in Zone C. Loaded trolleys then automatically move into Zone F, where one robot picks one panel at a time and places it on the tilt table. A second robot picks up the panel and places it between the dies of the first mechanical press. Other robots are located between the presses for handling the semi-shaped panel and finally the finished product is loaded on the offload conveyors.

Figure 7.5 demonstrates the application of the model to a selected mode of intervention. This relates to a dropped panel inside danger Zone F, as the direct result of a robotic gripper fault. This fault could be either the result of the gripper control or pneumatic system failure.

The task-based risk assessment approach (Figure 7.3) was used to evaluate the risks to a two-man maintenance crew involved in fault finding. The risk level was found within the ALARP 'as low as reasonably practicable' region (Chapter 6), which would warrant reduction, taking costs into account.

Figure 7.5 shows the application of the proposed model.

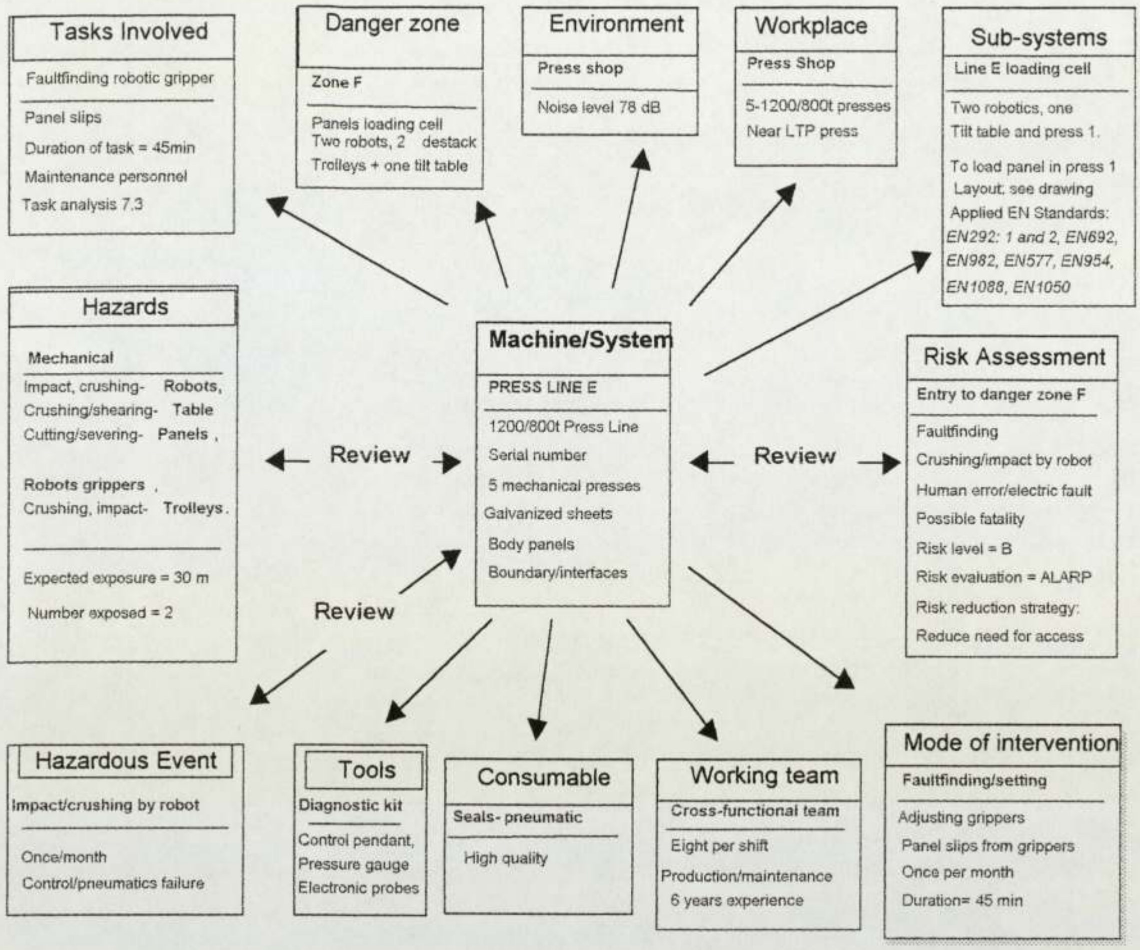


FIGURE 7.5 General Model Application

As a result of the risk assessment, an attempt was made to reduce the need for access into Zone F and to reduce the need for human intervention, in this case for fault finding while the robot is powered and the pneumatic power is on. As a result, a design change was made where the robotic gripper can be changed automatically without the need for access into the danger zone for any of the robots. This concept is shown in Figure 7.6.

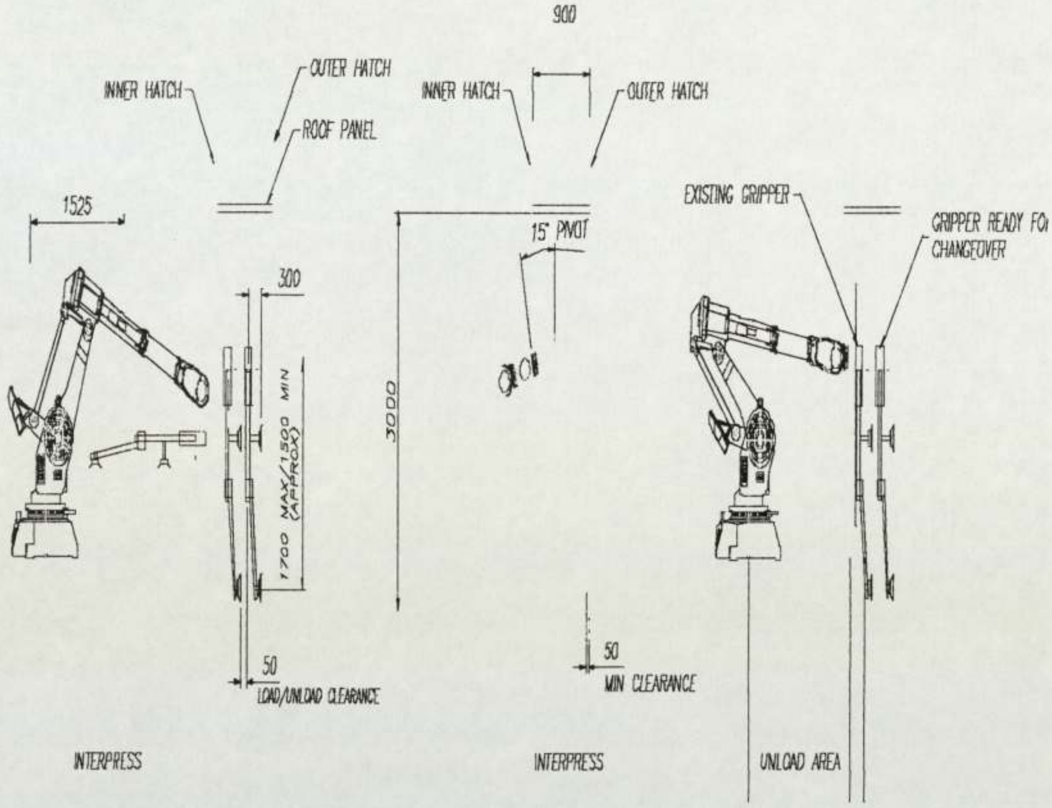


Figure 7.6 Automatic Changeover Of Robotic Gripper

Other safety measures resulting from the risk assessment included enhancements of the diagnostic systems. Figure 7.7 shows the overall improvements in E-Line safety systems, as a result of the application of the risk assessment model. The main guarding system is a mixture between rising screen interlocking safeguards and photoelectric devices.

Specific design safety measures resulting from risk assessment include the following: -

1. Modification of all five mechanical presses, taking account of (EN 692, 1998; EN 982, 1996).
2. Selection of Category 4 Safety-related parts of the control system according to (EN 954-1, 1996; EN 60204-1, 1996).
3. Software design to Safety Integrity Level (SIL) 3 according to (IEC 61508, 2000). Part handling is broken down into logic steps, using sequencers from process start to process finish.
4. Fixed and rising screen safeguards around Zones F and L, and rising screen guards between presses. The rising screen guards are interlocked with the process control system, taking account of (EN 1088, 1996), which is equivalent to type II protection according to (EN 201, 1997).
5. Design of the photoelectric devices in accordance with (EN 999, 1996; EN 50100-1, 1996).

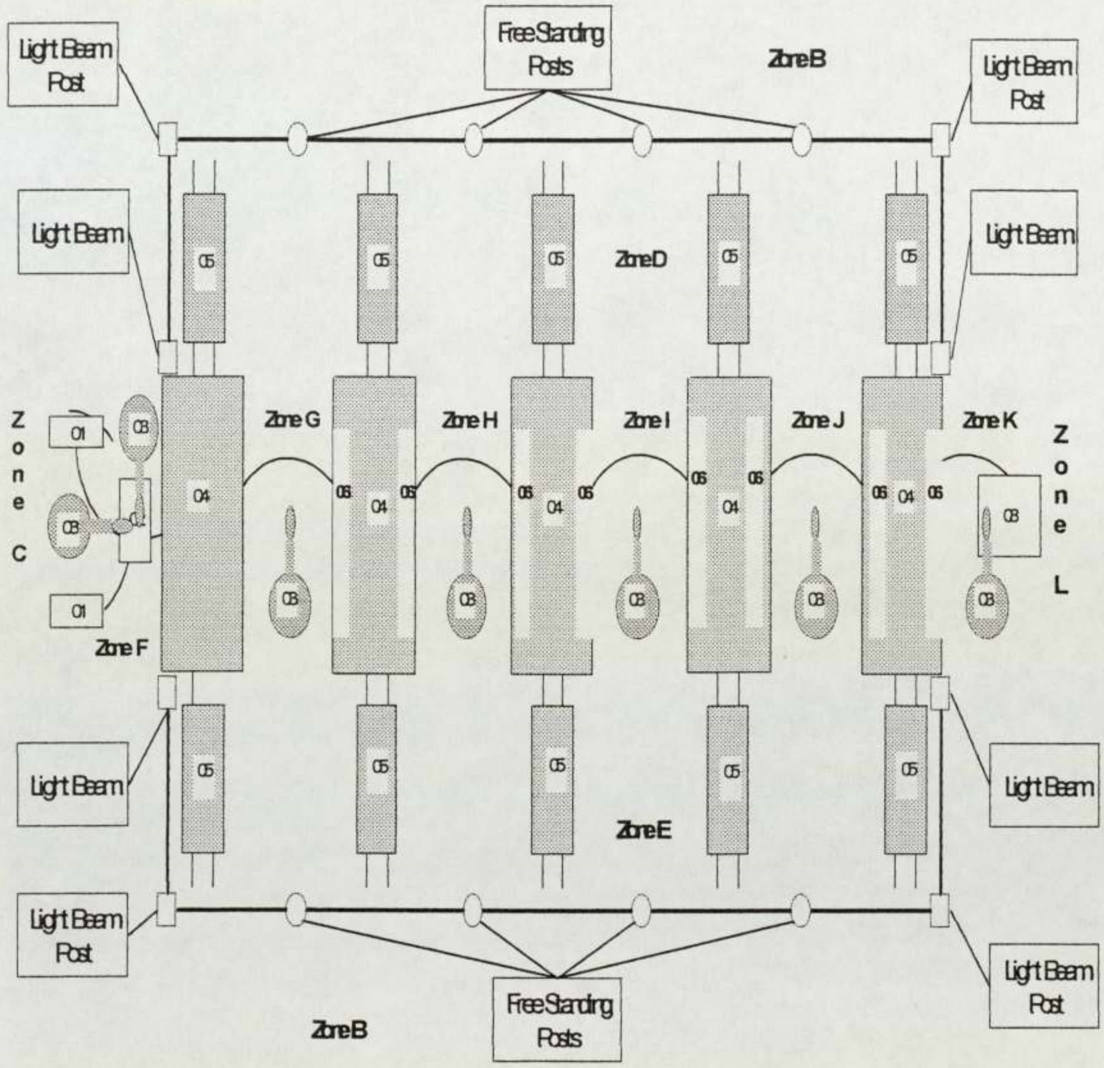


Figure 7.7 Safety Systems Design

The above example also shows that, in addition to the reduction of risks, significant improvements in productivity have been achieved. These have included the following:

1. Average press strokes = 8 per minute
2. Average die changeover time < 3 minutes
3. Offline setting time < 30 minutes

These productivity levels are regarded as world-class performance (Nicholas and Raafat 2000).

7.6 Summary Conclusion

This Chapter proposes a tool and methodology in order to provide practical guidance to machine/system designers, as to how health and safety can be integrated into the machinery design. A model based on risk assessment was developed which takes into account relevant EU directives and harmonised machinery safety standards.

The model will assist the designer in risk elimination, risk reduction and in selecting the most appropriate safety integrity levels for safeguards, safety devices and control systems with safety-related functions.

A case study was utilised to demonstrate the methodology. This highlighted that, in addition to demonstrating compliance with relevant health & safety legislation, improved productivity, downtime and world class performance could be realised in practice.

The thesis will now move on to consider the conclusions and recommendations resulting from the empirical research findings.

Chapter 8: Conclusions And Recommendations

8.1 Conclusions

The aim of the research was to assess the degree of suppliers' compliance with the requirements of the EU Machinery Directive, implemented in the UK as the SMSR. In order to achieve this aim it was necessary to set out a series of key research objectives. These have been fulfilled as follows: -

1. Chapters 2 and 3 undertook a critical analysis of machinery related legislative requirements and standards, with particular emphasis on the approach to technical harmonisation.
2. Chapter 4 studied the degree of suppliers' compliance with appropriate declarations of conformity and incorporation together with 'CE' marking requirements on a sample of machines supplied to the UK market between 1 January 1995 and 31 December 1998. The chapter reviewed and analysed relevant EU directives and EN standards indicated on the suppliers' declarations. In addition the chapter examined the supplied machinery in order to determine whether they were in fact safe.
3. Chapter 5 identified root causes for non-compliance with the EU Machinery Directive.
4. In Chapter 7 a model was developed which demonstrated how health and safety could be integrated into machinery design.

5. This Chapter will discuss the conclusions from the empirical research findings and make recommendations for change, where appropriate.
6. Chapter 9 identifies further research opportunities.

The analysis of the research findings has resulted in the formulation of the following conclusions. These represent serious challenges to the following: -

1. The Health & Safety Executive and Trading Standards Officers who enforce the EU Product Directives in the UK.
2. CEN-European Committee for Standardisation, as the data provided by the analysis in this study provides some feedback on the difficulties in implementing some of the key EU Harmonised Standards.
3. The employer who has to comply with the requirements of the Provision and Use of Work Equipment Regulations 1998 (PUWER). For example Regulation 11, the requirement to prevent access to dangerous parts of the machine or stop the movement of the dangerous part before any person enters the danger zone (Raafat and Nicholas, 1999).

8.1.1 The EU Machinery Directive

It is concluded that: -

1. The EHSRs are not written in specific terms, consequently their logic can appear somewhat unclear to machinery designers/manufacturers.

2. Some of the key EHSRs are duplicated throughout the various sections. This can only increase confusion regarding the interpretation of the EHSRs.
3. The UK government is opposing the changes to the conformity assessment procedure for Schedule 4 machinery. The empirical research findings have demonstrated that this view cannot be justified.

8.1.2 The EN Harmonised Machinery Safety Standards

It is concluded that: -

1. The EN standards are complicated and confusing, due to the fact that they require constant referencing and cross-referencing. Designer/suppliers must be provided with all of the necessary information 'to hand' from the onset if the EN standards are going to fulfil their intended aim.
2. The event tree contained within EN 954-1 has not been written in a logical sequence, consequently it allows designers/manufacturers to select a category of safety related parts of control system which is incompatible with the level of risk on the machine. In addition, EN 954-1 fails to quantify failure rates within the control system and consider the effects of probability within the overall risk assessment process.
3. EN 1088, unlike the C type fluid power standards, fails to describe the three different types of interlocking configuration. Once again, designers/suppliers

must be provided with all of the necessary information from the onset if the EN standards are going to fulfil their intended aim.

4. EN 775 is incompatible with the risk-based approach to machinery safety, due to the fact that it was converted from an ISO and consequently fails to indicate all of the hazards associated with industrial robotics. In addition, it does not indicate the most appropriate level of safeguards, which must be compatible with the level of risks associated with industrial robotics.
5. There is no informative annex; contained within EN 1050, which links the various risk assessment techniques to the overall framework.
6. The risk assessment process (EN 292-1) is driven by a list of hazards rather than by an examination of the tasks involved in operating, setting, adjusting, faultfinding and maintaining the machine.
7. There are no criteria to estimate and evaluate risks in a structured and systematic manner e.g. EN 1050, EN 292 etc.
8. No additional guidance is provided by either the DTI or the HSE on what is meant by the term 'safe'.

8.1.3 Designer, Manufacturer And Supplier Management Systems

It is concluded that designers and suppliers have not received adequate training in the following: -

1. Legislative requirements, which include all aspects of the EU Machinery Directive.

2. The content and implementation of the EN standards.
3. Risk assessment theory and practice.
4. How to verify the EHSRs in order to ascertain that the machine is in fact safe.

8.2 Recommendations

The analysis of the research conclusions has resulted in the formulation of the following recommendations.

8.2.1 The EU Machinery Directive

It is recommended that: -

1. The EHSRs are rewritten to provide better logic to their presentation and avoid the duplication that currently exists. This recommendation is in line with the proposed amendment to the EU Machinery Directive.
2. The UK government, based on the results of the empirical research findings, accepts the changes to the conformity assessment procedure previously highlighted.

8.2.2 The EN Harmonised Machinery Safety Standards

It is recommended that: -

1. A route map is produced for each of the EN standards, which this research has indicated are the least well known, referenced and correctly applied. The route map must contain a diagrammatic flow chart of the methodology to be adopted, in order to comply fully with the intended aims contained within the standard, and consequently satisfy the EHSRs. The route map must demonstrate the degree of inter-relationship with other EN standards. For example, the link between the type of interlocking arrangements and the category of control system integrity etc.
2. That event tree contained within EN 954-1 is rewritten utilising a logical sequence of events (Figure 6.4). The rewriting process should take into account the implications of probability within the risk assessment process, and quantify the effects of system reliability. The standard makers should seriously consider whether the use of event tree type analysis is appropriate. In reality, an approach based on the risk calculator may be better suited for the task of selecting the most appropriate category or safety integrity level.
3. That the diagrammatic detail, contained in all of the fluid power C-type standards, showing the three different types of interlocking configuration, is inserted into EN 1088.
4. That EN 775 is either withdrawn or rewritten. If it is rewritten then it must be constructed in a way as to be compatible with the risk- based approach. It must identify all hazards in the robotics cell and advise on the most

appropriate safety features, which must be compatible with the level of risk identified.

5. An informative annex is developed within EN 1050, in order to demonstrate how the various risk assessment techniques inter-relate. The standard makers should adopt the same approach as the one proposed by the American National Standards Institute (ANSI). This would offer more practical guidance to designers/manufacturers on the application of risk assessment. The development and use of the task-based approach to risk assessment is of fundamental importance to this recommendation.
6. The standard makers develop a system for the estimation and evaluation of risks, similar the HSE's tolerability of risk for nuclear power.
7. That the meaning of the word 'safe', defined by this thesis, is incorporated into the SMSR i.e. 'residual risks to health and safety and assets following control measures applied by the designer/manufacturer/supplier are reduced to a tolerable level for all foreseeable activities associated with the life-cycle of the machine'.

8.2.3 Designer, Manufacturer And Supplier Management Systems

It is recommended that designers/suppliers receive structured and systematic training in the following: -

1. Legislative requirements, to include all aspects of the EU requirements, the SMSR, HSWA, etc.

2. The content and implementation of the EN standards, to include their use in satisfying EHSRs.
3. Risk assessment theory and practice, to include how to undertake a structured and systematic risk assessment, which encompass the complete life cycle of the machine (design conception through to decommissioning and disposal).
4. Verification of the EHSRs to determine whether a machine is safe.
5. That the model discussed in the previous Chapter is utilised as a basis for integrating all aspects of health and safety into the machinery design.

The thesis will now move on to discuss future research opportunities.

Chapter 9: Future Research Work

This thesis has examined in detail the degree of compliance with the EU Machinery Directive. It has considered the first five years since the introduction of The SMSR. During this time many of the C type standards remained in provisional (pr) format. Future research should encompass the next five years of implementation of the harmonised regulations and standards in relation to machinery safety, where it is hoped that pr status will no longer remain a barrier to effective implementation. It should focus attention on a much larger sample of designers/suppliers, with a particular emphasis on those from the UK.

The research recommendations have identified a wide range of development areas that standard makers, enforcing authorities, designers/suppliers and end users need to address. It is hoped that all interested parties fully embrace these recommendations and take the appropriate action. If this is the case, their corrective actions should be fully analysed as part of a future research programme.

In addition, future research should examine the impact of the Provision and Use of Work Equipment Regulations 1998. Have these new regulations adequately addressed the criticisms of PUWER 1992, in particular the requirements of regulation 10 in ensuring that all machinery conforms to community requirements? It will be interesting to determine if this continues to be open to legal examination and interpretation.

Future research should also encompass a greater diversity of industries and machinery.

It is also proposed that the model for integrating health and safety into the machinery design is developed into a computer software package.

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Appendix 1

Declaration Certificate Templates

1. Declaration Of Conformity
2. Declaration Of Incorporation

Example Of EU Declaration Of Conformity

EU Declaration of Conformity

In accordance with: - **The Supply of Machinery (Safety) Regulations 1992**

We declare that this machine conforms with the Essential Health and Safety Requirements

Description of the machine, type and serial number: -

Business name and full address of manufacturer: -

All relevant **Product Directives** complied with: -

Machinery Directive (89/392/EEC), Low Voltage Directive (72/23/EEC) and EMC Directive (89/336/EEC) and all amendments thereto.

The machine complies with the following **Transposed Harmonised Standards**: -

EN 292-1, EN 292-2, EN 294, EN 349, EN954-1, EN 1050, EN 1088, EN 60204-1, ...

Other standards and technical specification utilised: -

IEC 61508

IDENTIFICATION of the person empowered to sign on behalf of the Company: -

Usually Managing Director

I certify that on 14th of January 1996 the above machine satisfies the EHSRs of all relevant product directives.

Signed.. Date............................

Example Of EU Declaration Of Incorporation

EU Declaration of Incorporation

In accordance with: - **The Supply of Machinery (Safety) Regulations 1992**

We declare that this machine conforms with the Essential Health and Safety Requirements

Description of the machine, type and serial number: -

Business name and full address of manufacturer: -

The machine complies with the following **Transposed Harmonised Standards**: -

EN 292-1, EN 292-2, EN 294, EN 349, EN954-1, EN 1050, EN 1088 EN 60204-1, ...

Other standards and technical specification utilised: -

IEC 61508

IDENTIFICATION of the person empowered to sign on behalf of the Company: -

Usually Managing Director

I certify that on 14th of January 1996 the above machine satisfies the EHSRs of all relevant product directives.

Signed.. Date..........................

NB This machine must not be used until it has been INCORPORATED into other relevant machinery and the CONFORMITY ASSESSMENT for that machinery has been undertaken by the responsible person.

Appendix 2

Inspection Of Documentation And Machinery

1. **Machinery Checklist**
2. **Hazard Identification Checklist**
3. **Task-based Risk Assessment Worksheet**
4. **Risk Calculator**

Inspection Of Documentation/Machinery

Supplier: - ………………………………………….

Type Of Machinery: - ……………..……………………..

Date: - ……………………..

Hierarchy Of Risk Control Measures

Q. Has risk reduction been achieved by design?

Yes/No

Q. Are the measures adequate?

Yes/No

Comments…………………………………………………………………………

…………………………………………………………………………………

Q. Have risks been reduced as a result of safeguarding techniques?

Yes/No

Q. Are the measures adequate?

Yes/No

Comments…………………………………………………………………………

……………………………………………………………………………………

………………………………………………………………………………

Q. Has information been provided warning of residual risks?

Yes/No

Q. Is the information adequate?

Yes/No

Comments..

....

Guarding Arrangements

Q. Are the guarding arrangements adequate?

Yes/No

Q. Do they comply with the requirements of BS EN953: 1998?

Yes/No

Q. Do they conform with the requirements of BS EN 294:1992/
BS EN 349:1993?

Yes/No

Q. Are they robust and securely held in place?

Yes/No

Q. Do they give rise to additional risk?

Yes/No

Q. Are they easy to bypass/render non-operational?

Yes/No

Q. Do they cause minimum obstruction of view?

Yes/No

Q. Are safety distances/minimum gaps adequate?

Yes/No

Comments..

....

....

Interlocking Arrangements

Q. Is the Type of interlocking arrangement compatible with the level of risk?

Yes/No

Q. Does it comply with the requirements of BS EN 1088:1996?

Yes/No

Comments..

....

....

Electrical

Q. Does the electrical system conform to the requirements of BS EN 60204-1:1992?

Yes/No

Comments...

....

....

Control System

Q. Is the Category of safety related parts of control system compatible with the level of risk?

Yes/No

Q. Does it conform to the requirements of BS EN 954-1:1996?

Yes/No

Comments...

....

....

Emergency Stops

Q. Is the Category of emergency stop compatible with the level of risk?

Yes/No

Q. Does it conform to the requirements of BS EN 418:1992?

Yes/No

Comments...

....

....

Fluid Power Systems

Q. Does the system conform with the requirements of BS EN 982:1996 and BS EN 983:1996?

Yes/No

Comments...

....

....

Trip Devices/Two-handed Controls

Q. Are the trip/two-handed devices compatible with the level of risk?

Yes/No

Q. Do they conform to the requirements of pr EN 50100-1:1994 and BS EN 574:1997?

Yes/No

Comments...

....

....

'C' Type EN Standards

Q. Has the relevant 'C' Type Standard been indicated/utilised?

Yes/No

Q. Has the 'C' Type Standard been correctly applied?

Yes/No

Comments...

....

....

Instructions/Safe Access/Warning Notices

Q. Have instructions for commissioning been documented/provided?

Yes/No

Q. Are they adequate?

Yes/No

Q. Have instructions for safe systems of work been documented/ provided?

Yes/No

Q. Are they adequate?

Yes/No

Q. Has safe access been provided for normal operation of machine?

Yes/No

Q. Have instructions for safe maintenance, setting, fault finding, cleaning etc. been provided?

Yes/No

Q. Are they adequate?

Yes/No

Q. Has safe access been provided for maintenance, setting, fault finding cleaning, etc.?

Yes/No

Q. Have warning notices been posted?

Yes/No

Q. Are they adequate?

Yes/No

Q. Do all instructions and warning notices comply with the EHSRs?

Yes/No

Comments...

....

....

....

'CE' Marking

Q. Has the 'CE' mark been properly affixed?

Yes/No

Comments...

....

....

Declaration Of Conformity/Incorporation

Q. Has a Declaration Of Conformity/Incorporation been issued?

Yes/No

Q. Does the Declaration conform to the EC Machinery Directive?

Yes/No

Comments...

....

....

Is The Machine In Fact Safe

Q. Does the machine appear to be in fact safe?

Yes/No

Comments...

....

....

....

Additional

Comments...

....

....

....

Hazard Identification Checklist

Mechanical Hazards	Yes/No	Hazard Description
1.1 Crushing		
1.2 Shearing		
1.3 Cutting/Severing		
1.4 Entanglement		
1.5 Drawing-in/Trapping		
1.6 Impact		
1.7 Stabbing/Puncture		
1.8 Friction/Abrasion		
1.9 High Pressure Fluid Injection		
1.10 Slips/Trips/Falls		
1.11 Falling/Moving Object		
1.12 Other Mechanical Hazard		
2.0 Electrical Hazards		
2.1 Direct Contact		
2.2 Indirect Contact		
2.3 Electrostatic		
2.4 Short Circuit/Overload		
2.5 Source Of Ignition		
2.6 Other Electrical Hazards		
3.0 Radiation		
3.1 Lasers		
3.2 Electro-magnetic Fields		
3.3 Ionizing/Non-ion. Radiation		
3.4 Other Radiation Hazards		
4.0 Hazardous Substances		
4.1 ToXic Fluids		
4.2 Toxic Gas/Mist/Fumes		
4.3 Flammable Fluids		
4.4 Flammable Gas/Mist/Fumes		
4.5 Explosive Substances		
4.6 Biological Substances		
4.7 Other Hazardous Substances		
5.0 Work Activity Hazards		
5.1 Highly Repetitive Actions		
5.2 Stressful Posture		
5.3 Lifting/Handling		
5.4 Mental Overload/Stress		
5.5 Visual Fatigue		
5.6 Poor Work Place Design		
5.7 Other Work Place Hazards		
6.0 Work Environment		
6.1 Localized Hot Surfaces		
6.2 Localized Cold Surfaces		
6.3 Significant Noise		
6.4 Significant Vibration		
6.5 Poor Lighting		
6.6 Hot/Cold Ambient Temperature		
6.7 Other Environmental Hazards		

Task-based Risk Assessment Worksheet

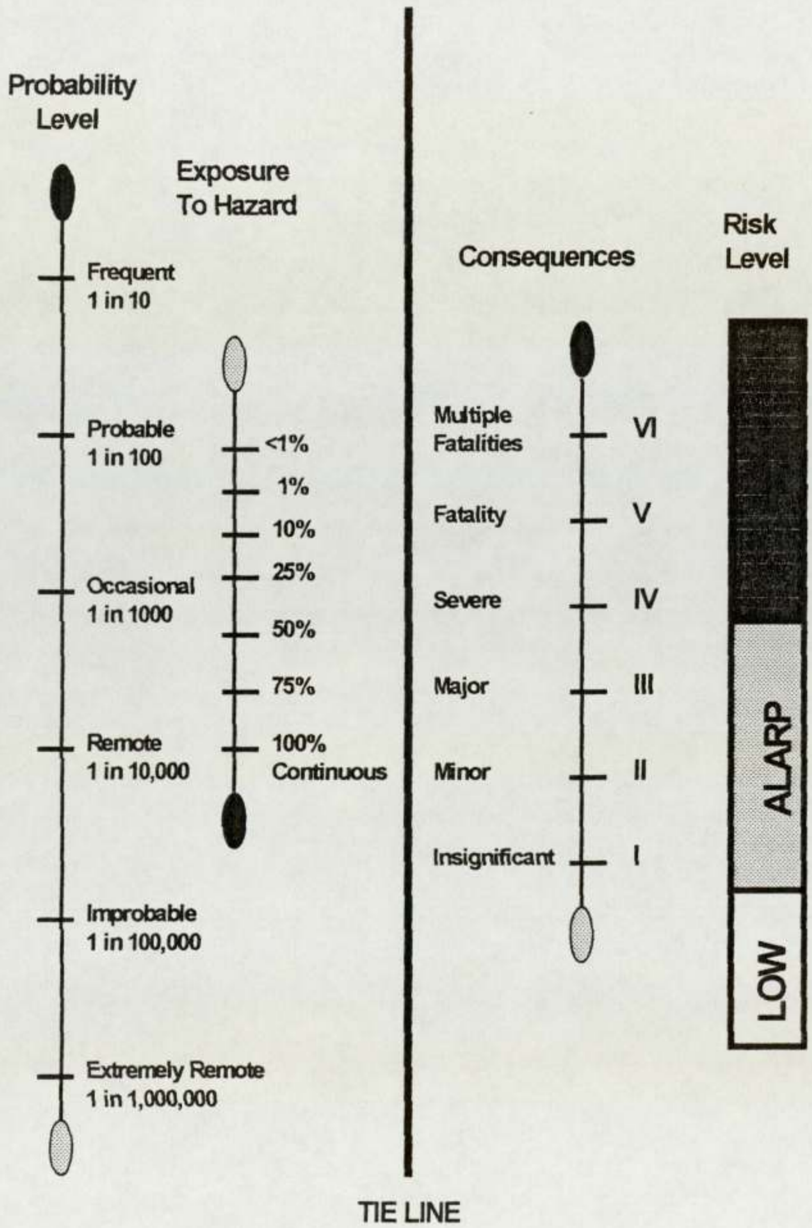
Name Of Assessor: -

Name Of Machine: - Supplier: - Date: -

ACTIVITY TYPE	HAZARDOUS EVENTS Errors/Failure	POSSIBLE CAUSES	CONSEQUENCES	RISK LEVEL	CONTROL MEASURES ACTION REQUIRED

The Risk Calculator (Source: Raafat 1996)

Consequence:	I	II	III	IV	V	VI
Personnel	Insignificant	Minor	Major	Severe	Fatality	Multi-Fatalities
Economic	<£1000	<£10,000	<£100,000	<£1,000,000	>£1,000,000	Total Loss
Environment	Minor	Short Term Damage	Major	Severe	Widespread Damage	Catastrophe



Inspection Of Documentation/Machinery - Types Of Non-conformity - Worksheet

Description	Yes/No
Hierarchy of risk control measures conform with EH&SRs	
Guards constructed according to EN 953	
Guards conform with EN 294/EN 349 (safety distances)	
Interlocking devices conform with EN 1088	
Electrical equipment conforms with EN 60204-1	
Control system conforms with EN 954-1	
Emergency stops conform with EN 418/EN 954-1	
Safety requirements for fluid power systems conform with EN 982/EN 983	
Trip devices/two handed controls conform with relevant B1/B2 Standards	
Relevant C-Standard is indicated/ utilised	
Relevant C-Standard correctly used	
Instructions for Commissioning are documented/adequate	
Instructions for safe systems of work are adequate/documented	
Safe access provided for normal operation of machine	
Instructions for safe maintenance, cleaning.........are provided	
Safe access provided for setting, maintenance, fault finding, cleaning	
Warning notices are adequate	
CE' mark affixed to machine (where relevant)	
Declaration of Conformity/ Incorporation issued	
Declaration Certificate is adequate	
The machine is '*Safe*'	

Appendix 3

Semi-structured Interviews – Data Collection

1. Question Set
2. Interview Worksheet

Semi Structured Interviews - Data Collection

Supplier: - ....

Type Of Machinery: -..

Date: - ....

Q1A. What is the root to demonstrating compliance with the requirements of the EU Machinery Directive?

Response..

....

Q1B. Who do these requirements apply to?

Response..

Q2. How are the Harmonised machinery safety EN Standards structured?

Response..

....

Q3. Which specific EN Standards apply to your product?

Response..

....

....

Q4. What is the status of old style prescriptive British machinery safety Standards?

Response...

....

Q5. What is a Technical File?

Response...

....

Q6. What should be included in the Technical File?

Response...

....

Q7. What are the Essential Health and Safety Requirements?

Response...

....

Q8. What is your level of understanding of EN Standards?

Response...

....

Q9A. What training have you and your colleagues received in relevant Legislative requirements and Standards?

Response...

....

Q9B. Do you feel that the training was adequate?

Response...

Q10A. What training have you and your colleagues received in risk assessment?

Response...

Q10B. Do you feel that the training was adequate?

Response..

Q11. What is the status of provisional (pr) En Standards?

Response..

Q12. What 'C' Type Standard exists for your product?

Response...

Q13. What is the role of 'B1' and'B2' Type EN Standards?

Response...

....

Q14. Which EN Standards require a risk assessment to be undertaken?

Response...

....

Q15. What is your opinion of the Harmonised Regulations And EN Standards?

Response...

....

Q16. What kind of guidance do the EN Standards provide?

Response...

....

Q17. Who should be responsible for the EC Standards/documentation?

Response...

....

Q18. Which EN Standards were given to the designer?

Response..

....

Q19. What is the structure and content of the conformity assessment procedure?

Response..

....

Q20. What are the specific requirements of BS EN 1050:1997?

Response..

....

Q21. Where is the risk assessment for the machine?

Response..

Q22. How have you ensured that your risk assessment has encompassed the life cycle of the machine?

Response..

....

Q23. What is the difference between a Declaration Of Conformity and Declaration Of Incorporation?

Response..

....

Q24. When should the 'CE' Mark be affixed?

Response..

....

Q25. How did you devise safe systems of work for the installation and commissioning stage?

Response..

....

Q26. What are the legal implications if you do not comply with the requirements of the EC Machinery Directive?

Response..

....

Q27. What information do you need to provide for access into the machine by operators?

Response..

....

Q28. What information do you need to provide for access into the machine for maintenance, setting, adjusting, fault finding, cleaning etc.

Response..

....

Q29. What other EC Directives apply to your product?

Response..

....

Q30. How did you assess foreseeable misuse?

Response..

....

Additional

Comments...

....

....

....

Semi-structured Interviews - Worksheet

Description	Response
Unaware of the requirements of the EU Machinery Directive	
Assumes that 'CE Marking and Declarations is a customer requirement	
Unaware of the structure of the Transposed Harmonised Standards	
Unsure which EN Standard applies to their product	
Assume that British Standards satisfies EH&SR's	
Unaware of the requirement for and content of a Technical File	
Supplier management did not provide Standards for designers	
Unaware of relevant Essential Health and Safety Requirements 'EHSRs'	
Unaware of other EU Directives relevant to machine	
Insufficient/No training on relevant Legislation and Standards	
Insufficient/No training on machinery risk assessment	
Assume that prEN Standards do not apply as they are provisional	
Unaware that a 'C'-Type Standard exists for their product	
Unaware of the role of European Standards e.g. B1 and B2 Type	
Unaware of the EN Standards which require risk assessment	
Finds the EN Standards complicated and confusing	
The EN Standards do not provide clear guidance for designers	
See compliance with the EU Standards/documentation as a Quality Systems function	

Description	Response
Unaware of the correct structure and content of the conformity assessment	
Unaware of the specific requirements for EN 1050	
Did not/could not provide a risk assessment	
Unaware of the requirements that risk assessment should cover the life cycle of the machine	
Unaware of the difference between Declarations of Conformity and Incorporation	
Unclear when a CE-Mark should be affixed	
Unaware that safe systems of work need to be documented for the installation and commisioning stages	
Unaware of the Suppliers legal position if found not to comply	
Unaware of the need to provide safety instructions for access into machine by operators	
Unaware of the need to provide safety instructions for access into machine for maintenance, setting, adjusting, fault finding, cleaning etc.	
Unaware of the requirement that the design should accommodate foreseeable misuse	

Appendix 4

List Of Transposed Harmonised Standards

Current List Of Transposed Harmonised Standards

(Earth Moving Equipment Excluded)

BS EN 201: 1997	Rubber and plastic machines - Injection moulding machines - Safety requirements.
BS EN 289: 1993	Safety of machinery - Rubber and Plastics machinery - Compression and transfer moulding presses - Safety requirements for design.
BS EN 292-1: 1991	Safety of machinery - Basic concepts and general principles for design - Part 1: Basic terminology and methodology.
BS EN 292-2: 1991	Safety of machinery - Basic concepts and general principles for design - Part 2: Technical principles and specifications.
BS EN 292-2/A1: 1995	Safety of machinery - Basic concepts and general principles for design - Part 2: Technical principles and specifications.
BS EN 294: 1992	Safety of machinery - Safety distances to prevent danger zones being reached by the upper limbs.
BS EN 349: 1993	Safety of machinery - Minimum gaps to avoid crushing of parts of the human body.
BS EN 415-4: 1997	Safety of packaging machines - Part 4: Palletisers and depalletisers.
BS EN 418: 1992	Safety of machinery - Emergency stop equipment, functional aspects - Principles for design.

BS EN 422: 1995 Rubber and plastic machines - Safety - Blow moulding machines intended for the production of hollow articles - Requirements for design and construction.

BS EN 457: 1992 Safety of machinery - Auditory danger signals - General requirements, Design and testing. (ISO 7731: 1986 modified).

BS EN 547-1: 1996 Safety of machinery - Human body measurements - Part 1:Principles for determining the dimensions required for openings for the whole body access into machinery.

BS EN 547-2: 1996 Safety of machinery - Human body measurements - Part 2: Principles for determining the dimensions required for access openings.

BS EN 547-3: 1996 Safety of machinery - Human body measurements - Part 3: Anthropometrical data.

BS EN 563: 1994 Safety of machinery - Temperatures of touchable surfaces - Ergonomics data to establish temperature limit values for hot surfaces.

BS EN 574: 1996 Safety of machinery - Two-hand control devices - Functional aspects - Principles for design.

BS EN 614-1: 1995 Safety of machinery - Ergonomic design principles - Part 1: Terminology and general principles.

BS EN 626-1: 1994 Safety of machinery - Reduction of risks to health from hazardous substances emitted by machinery - Part 1: Principles and specifications for machinery manufacturers.

BS EN 626-2: 1996 Safety of machinery - Reduction of risk to health from hazardous substances emitted by machinery - Part 2: Methodology leading to verification procedures.

BS EN 692: 1996 Mechanical presses - Safety.

BS EN 775: 1992 Manipulating industrial robots - Safety. (ISO 10218: 1992, modified).

BS EN 791: 1995 Drill rigs - Safety.

BS EN 809: 1998 Pumps and pump units for liquids - Common safety requirements.

BS EN 811: 1996 Safety of machinery - Safety distances to prevent danger zones being reached by the lower limbs.

BS EN 818-1: 1996 Short link chain for lifting purposes - Safety - Part 1: General conditions of acceptance.

BS EN 842: 1996 Safety of machinery - Visual danger signals - General requirements, design and testing.

BS EN 848-1: 1998 Safety of woodworking machines - One side moulding machines with rotating tool - Part 1: Single spindle vertical moulding machines.

BS EN 848-2: 1998 Safety of woodworking machines - One side moulding machines with rotating tool - Part 2: Single spindle hand fed/ integrated fed routing machines.

BS EN 859: 1997 Safety of woodworking machines - Hand-fed surface planing machines.

BS EN 860: 1997 Safety of woodworking machines - One side thickness planing machines.

BS EN 861: 1997 Safety of woodworking machines - Surface planing and thicknessing machines.

BS EN 869: 1997 Safety requirements for high pressure metal die casting units.

BS EN 894-1: 1997 Safety of machinery - Ergonomics requirements for the design of displays and control actuators - Part 1: General principles for human interactions with displays and control actuators.

BS EN 894-2: 1997 Safety of machinery - Ergonomics requirements for the design of displays and control actuators - Part 2: Displays.

BS EN 940: 1997 Safety of woodworking machines - Combined woodworking machines.

BS EN 953: 1997 Safety of machinery - Guards - General requirements for the design and construction of fixed and moveable guards.

BS EN 954-1: 1996 Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design.

BS EN 981: 1996 Safety of machinery - System of auditory and visual danger and information signals.

BS EN 982: 1996 Safety of machinery - Safety requirements for fluid power systems and their components - Hydraulics.

BS EN 983: 1996 Safety of machinery - Safety requirements for fluid power systems and their components - Pneumatics.

BS EN 1012-1: 1996 Compressors and vacuum pumps - Safety requirements - Part 1: Compressors.

BS EN 1012-2:1996 Compressors and vacuum pumps - Safety requirements - Part 2: Vacuum Pumps.

BS EN 1032: 1996 Mechanical vibration - Testing of mobile machinery in order to determine the whole-body vibration emission value - General.

BS EN 1033: 1995 Hand-arm vibration - Laboratory measurement of vibration at the grip surface of hand-guided machinery - General.

BS EN 1037: 1995 Safety of machinery - Prevention of unexpected start-up.

BS EN 1050: 1996 Safety of machinery - Principles for risk assessment.

BS EN 1088:1996 Safety of machinery - Interlocking devices associated with guards - Principles for design and selection.

BS EN 1093-1: 1998 Safety of machinery - Evaluation of the emission of airborne hazardous substances - Part 1: Selection of test methods.

BS EN 1114-1: 1996 Rubber and plastic machines - Extruders and extrusions lines - Part 1: Safety requirements for extruders.

BS EN 1114-2: 1998 Rubber and plastics machines - Extruders and extrusion lines - Part 2: Safety requirements for die-face palletiser.

BS EN 1127-1: 1997 Explosive atmospheres - Explosion prevention and protection - Part 1: Basic concepts and methodology.

BS EN 1175-1: 1998 Safety of industrial trucks - Electrical requirements - Part 1: General requirements for battery-powered trucks.

BS EN 1299: 1997 Mechanical vibration and shock - Vibration isolation of machines - Information for the application of source isolation.

BS EN 1398: 1997 Dock levellers.

BS EN 1417: 1996 Rubber and plastics machines - Two roll mills - Safety requirements.

BS EN 1454: 1997 Portable, hand-held, internal combustion cutting-off machines - Safety.

BS EN 1495: 1997 Lifting platforms - Mast climbing work platforms.

BS EN 1525: 1997 Safety of industrial trucks - Driverless trucks and their systems.

BS EN 1526: 1997 Safety of industrial trucks - Additional requirements for automated functions on trucks.

BS EN 1550: 1997 Machine-tools safety - Safety requirements for the design and construction of work holding chucks.

BS EN 1570: 1998 Safety requirements for lifting tables.

BS EN 1612-1: 1997 Rubber and plastics machines - Reaction moulding machines - Part 1: Safety requirements for metering and mixing units.

BS EN 1672-2: 1997 Food processing machinery - Basic concepts - Part 2: Hygiene requirements.

BS EN 1678: 1998 Food-processing machinery - Vegetable cutting machines - Safety and hygiene requirements.

BS EN 1679-1: 1998 Reciprocating internal combustion engines - Safety - Part 1: Compression ignition engines.

BS EN 1760-1: 1997 Safety of machinery - Pressure sensitive protective devices. General principles for the design and testing of pressure sensitive mats and pressure sensitive floors.

BS EN ISO 3743-1: 1995 Acoustics - Determination of sound power levels of noise sources - Engineering methods for small, movable sources in reverberant fields - Part 1: Compression method for hard-walled test rooms. (ISO 3743-1: 1994).

BS EN ISO 3743-2: 1996 Acoustics - Determination of sound power levels of noise sources using sound pressure - Engineering methods for small, movable sources in reverberant fields - Part 2: Methods for special reverberation test rooms. (ISO 3743-2: 1994).

BS EN ISO 3744: 1995 Acoustics - Determination of sound power levels of noise sources using sound pressure - Engineering method in an essentially free field over a reflecting plane. (ISO 3744: 1994).

BS EN ISO 3746: 1995 Acoustics - Determination of sound power levels of noise sources using sound pressure - Survey method using an enveloping measurement surface over a reflecting plane. (ISO 3746: 1995).

BS EN ISO 4871: 1997 Acoustics - Declaration and verification of noise emission values of machinery and equipment. (ISO 4871: 1996).

BS EN ISO 7235: 1995 Acoustics - Measurement procedures for ducted silencers Insertion loss, flow noise and total pressure loss. (ISO 7235: 1991).

BS EN ISO 7250: 1997	Basic human body measurements for technological design. (ISO 7250: 1996).
BS EN ISO 8662-4: 1995	Hand-held portable power tools-Measurement of vibrations at the handle - Part 4: Grinders. (ISO 8662-4: 1994).
BS EN ISO 8662-6:1995	Hand-held portable power tools - Measurement of vibrations at the handle - Part 6: Impact drills. (ISO 8662-6: 1994).
BS EN ISO 11102-1: 1997	Reciprocating internal combustion engines - Handle starting equipment - Part 1: Safety requirements and tests. (ISO 11102-1:1997).
BS EN ISO 11201: 1995	Acoustics - Noise emitted by machinery and equipment - Measurement of emission sound pressure levels at a workstation and at other specified positions - Engineering method in an essentially free field over a reflecting plane. (ISO 11201: 1995).
BS EN ISO 11202: 1995	Acoustics - Noise emitted by machinery and equipment - Measurement of emissions sound pressure levels at workstation and other specified positions - Survey method *in situ*. (ISO 11202: 1995).
BS EN ISO 11203: 1995	Acoustics - Noise emitted by machinery and equipment - Determination of emission sound pressure levels at a workstation and at other specified positions from the sound power level. (ISO 11203: 1995).

BS EN ISO 11204: 1995	Acoustics - Noise emitted by machinery and equipment - Measurement of emission sound pressure levels at a workstation and at other specified positions - Method requiring environmental corrections. (ISO 11204: 1995).
BS EN ISO 11546-1: 1995	Acoustics - Determination of sound insulation performance of enclosures - Part 1: Measurement under laboratory conditions (for declaration purposes). (ISO 11546-1: 1995).
BS EN ISO 11688-1: 1998	Acoustics - Recommended practice for the design of low-noise machinery and equipment - Part 1: Planning. (ISO/TR 11688-1: 1995).
BS EN ISO 11691: 1995	Acoustics - Measurement of insertion loss of ducted silencers without flow - Laboratory survey method. (ISO 11691: 1995).
BS EN ISO 11957: 1996	Acoustics - Determination of sound insulation performance of cabins - Laboratory and in situ measurements. (ISO 11957: 1996).
BS EN ISO 12001: 1996	Acoustics - Noise emitted by machinery and equipment - Rules for drafting and presentation of a noise test code. (ISO 12001: 1996).
BS EN 12626: 1997	Safety of Machinery - Laser Processing Machines - Safety Requirements. (ISO 11553: 1996 modified).
BS EN 23741: 1991	Acoustics - Determination of sound power levels of noise sources - Precision methods for broadband sources in reverberation rooms. (ISO 3741: 1988).

BS EN 23742: 1991	Acoustics - Determination of sound power levels of noise sources - Precision method for discrete-frequency and narrow-band sources in reverberation rooms. (ISO 3742: 1988).
BS EN 25136: 1993	Acoustics - Determination of sound power radiated into a duct by fans-In-duct method. (ISO 5136: 1990 and technical corrigendum 1: 1993).
BS EN 28662 Part 1 1992	Hand-held portable power tools - Measurement of vibrations at the handle - Part1: General. (ISO 8662-1: 1988).
BS EN 31252: 1994	Laser and laser-related equipment - Laser device - Minimum requirements for documentation. (ISO 11252: 1993).
BS EN 31253: 1994	Laser and laser-related equipment - Laser device - Mechanical interfaces. (ISO 11253: 1993).
BS EN 60204 Part 1 1992	Safety of machinery - Electrical equipment of machines - Part 1: General requirements.