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ASSESSMENT OF PROCESS SAFETY PERFORMANCE IN SEVESO ESTABLISHMENTS

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Abstract

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This study was begun within Tukes, The Finnish Safety and Chemicals Agency, in 2009 with the purpose of observing the effective process safety procedures used by operators and authorities in other European countries. For the study, a group of inspectors visited nine establishments belonging to three companies in seven countries. The agenda for the visits was based on the inspection agenda of Finnish Seveso establishments: recognition of the requirements of legislation, management and personnel commitment, risk assessment and management of change, identification of safety requirements, emergency preparedness and site tour. The establishments were also assessed based on the current scoring system used by Tukes. The aim of the study was to deepen knowledge of inspection procedures within Tukes and develop process safety in Finland.

The companies which participated this study were known to have high safety levels. The establishments visited in Finland were mainly chosen based on the inspection schedules of Tukes, while those visited in other countries were chosen by the companies concerned. As a result, the visited establishments cannot be considered representative of all Seveso establishments. If the companies and establishments had been randomly chosen, this would probably have had an effect on the comparative results.

The visiting group made no observations of serious or significant deficiencies, but many good practices were noted which could be applied in other establishments. There were differences in safety procedures between the companies, even if they have common safety management systems and policies in place. The study also included observations on the differences between the authorities and their practices, and the requirements placed on establishments. The visiting group gave scores to each establishment based on the scoring system used in Finnish inspections. These scores can be used to compare safety levels between establishments based on a range of seven topics. The scores given ranged between 2 and 4.5 (scale 0–5), while the total average score given to establishments varied little, ranging from 3.1 to 4.1.

When analysing the results of the study, ideas were formed on how Tukes' scoring system might be developed. The system has been in use since 2005 and has a range of positive aspects. For the purposes of this study, the current scoring system has therefore been used as a basis for the newly developed system. The greatest change between the

current and the new system lies in the fact that the new scoring system includes several detailed questions under each topic (67 questions in total), all of which are given their own score. The average score for each topic can still be calculated and used in the same way as in the current system, even though the scale has been changed from an eleven-step -scale to a four-step -scale. The new system was tested by Tukes inspectors in five inspections conducted in 2013–2014. In each case, the testing was performed by a pair of inspectors who mainly gave their scores independently. In all five test inspections, the developed scoring system was also tested as a self-assessment tool by the establishments.

Although the testing of the new scoring system revealed that many aspects are still in need of development, the system received positive feedback from the inspectors testing it. A total of 335 questions were presented during the test inspection, of which 67% were answered by both inspectors. Of the questions answered, 77% comprised identical answers. The number of questions answered by both the inspectors and self-assessors varied between 24 and 59. The self-assessors agreed with the inspectors in the case of 33%–82% of the questions answered. Self-assessment constituted a completely new system for the establishments, which were not provided with any guidance or training the use of the new system.

The new scoring system provides establishments with more information in the form of more detailed questions with the related answers. For new inspectors, the developed scoring system is easier to learn than the current one, due to its more precise questions and more clearly defined scale.

The questions require more development before the adoption of the new scoring system in inspections by Tukes. There is also a need for a guide and orientation for the inspectors on how to use the system. In particular, if the system is used as a self-assessment tool, there is a need for a guide on how to answer the questions. For Tukes, use of a self-assessment tool would represent a new way of co-operating with inspected establishments. It can be assumed that the extent of unanimity achieved among inspectors and between self-assessors and inspectors will increase due to the test inspections.

If Tukes renews its scoring system, it would be wise to renew the entire reporting system for inspections at the same time; e.g. inspection reports could be lighter and the scoring table could be included as an appendix.

Keywords: process safety, safety management, Seveso inspection, safety performance, safety procedures, inspection assessment, self-assessment

Tiivistelmä

Tämä tutkimus sai alkunsa vuonna 2009 Turvallisuus- ja kemikaalivirasto Tukesin kiinnostuksesta nähdä sekä toiminnanharjoittajan että viranomaisen toimesta tehtäviä hyviä prosessiturvallisuuden käytäntöjä muissa Euroopan maissa. Tapaustutkimuksessa ryhmä tarkastajia vieraili yhdeksällä laitoksessa kolmesta yrityksestä seitsemässä maassa. Vierailujen ohjelma noudatti Suomen Seveso-laitosten tarkastusohjelmaa: lainsäädännön vaatimusten tunnistaminen, johdon ja henkilöstön sitoutuminen, riskien arviointi ja muutosten hallinta, turvallisuusvaatimusten määrittely, poikkeustilanteisiin varautuminen ja tehdaskierros. Laitokset arvioitiin Tukesissa käytössä olevalla arviointimenetelmällä. Tämän tutkimuksen tarkoitus oli syventää Tukesin tietämystä ja kehittää prosessiturvallisuutta Suomessa.

Tutkimukseen osallistuneiden yritysten tiedettiin olevan hyvällä tasolla prosessiturvallisuudessa. Vieraillut laitokset Suomessa valittiin pääosin tarkastusten aikataulujen perusteella. Muissa maissa vierailun kohteena olleet laitokset valitsivat yritykset itse eivätkä ne sen vuoksi edustaneet kaikkia Seveso-laitoksia. Jos yritykset ja laitokset olisi valittu satunnaisesti, olisi tämä todennäköisesti vaikuttanut vertailutuloksiin.

Käynneillä ei havaittu vakavia puutteita mutta havaintoja tehtiin monista hyvistä käytännöistä, joita voisi ottaa käyttöön myös muilla laitoksilla. Turvallisuuskäytännöissä oli eroja, vaikka yrityksillä oli käytössään yhteiset turvallisuusjohtamisjärjestelmät ja politiikat. Käynneillä tehtiin myös havaintoja eroavaisuuksista viranomaisten vaatimuksissa ja käytännöissä. Vieraileva ryhmä myös arvioi laitoksen samalla tavoin kuin Suomen tarkastuksilla. Näiden arviointien avulla laitosten turvallisuustasoja voidaan verrata toisiinsa seitsemällä eri osa-alueella. Annetut arviot vaihtelivat välillä 2 ja 4,5 (asteikko 0-5) eikä kokonaiskeskiarvo vaihdellut paljon, välillä 3,1 ja 4,1.

Vertailututkimusten tuloksia analysoitaessa nousi esille ideoita siitä, miten Tukesin arviointimallia voisi kehittää. Menetelmä on ollut käytössä vuodesta 2005 ja sillä on monia hyviä puolia. Sen vuoksi menetelmä on ollut pohjana tässä kehitettävälle uudelle menetelmälle. Suurin muutos nykyistä menetelmää kehitettäessä on tehty laadittaessa jokaisen osa-alueen alle useita yksityiskohtaisempia kysymyksiä (yhteensä 67 kysymystä). Näistä jokaiselle kysymykselle annetaan oma arvio. Nykyisen menetelmän tavoin uudessakin menetelmässä voidaan laskea ja hyödyntää osa-alueiden keskiarvoja. Asteikkoa on muutettu 11-tasoisesta (0-5) nelitasoiseksi (0-3). Uutta menetelmää on testattu viidellä tarkastuksella vuosina 2013–2014. Testaus tehtiin aina tarkastusparin toimesta molempien tarkastajien antaessa omat arvionsa pääasiassa itsenäisesti. Kaikilla viidellä tarkastuksella menetelmää testattiin myös itsearviointiin toiminnanharjoittajien toimesta.

Kehitetyn arviointimenetelmän testaus osoitti, että siinä on vielä monia asioita, jotka vaativat kehittämistä, mutta sitä testanneet tarkastajat antoivat siitä yleensä positiivista

palautetta. Testitarkastuksilla oli yhteensä 335 kysymystä, joista molemmat tarkastajat vastasivat 67 %:iin. Vastatuista kysymyksistä 77 %:ssa oli identtiset vastaukset. Kysymykset, joihin sekä tarkastajat että itsearvioijat olivat vastanneet, vaihtelivat välillä 24 ja 59. Itsearvioinnit olivat yksimielisiä tarkastajien kanssa 33 %–82 % vastatuista kysymyksistä. Laitokset eivät ole tottuneet tekemään itsearviointia viranomaisille, minkä vuoksi menetelmä oli niille täysin uusi. Laitoksia ei myöskään koulutettu menetelmään käyttöön millään tavalla.

Kehitetty arviointimalli antaa laitoksille enemmän tietoa yksityiskohtaisempien kysymysten ja niiden vastausten avulla. Uusille tarkastajille kehitetty arviointimenetelmä on helpompi oppia kuin nykyinen menetelmä yksityiskohtaisempien kysymysten ja tarkemmin määritellyn arviointiasteikon avulla.

Kehitettyä arviointimenetelmää tulee kehittää edelleen ennen sen mahdollista käyttöönottoa Tukesin tarkastuksilla. Menetelmän käyttö vaatii myös erillisen käyttöohjeen ja perehdytyksen. Ohjeen tärkeys korostuu erityisesti silloin, jos menetelmää käytetään itsearviointiin. Itsearvioinnin käyttö olisi myös Tukesille uusi tapa tehdä yhteistyötä laitosten kanssa. Voidaan olettaa, että yksimielisyys tarkastajien kesken ja itsearvioijien ja tarkastajien välillä kasvaa testausvaiheesta.

Jos Tukesin arviointimenetelmää uusitaan, olisi samaan aikaan viisasta uudistaa myös tarkastusten raportointia kokonaisuutena; esim. tarkastuspöytäkirjat voisivat olla kevyempiä niin, että arviointilomake olisi niiden liitteenä.

Avainsanat: prosessiturvallisuus, turvallisuusjohtaminen, Seveso-tarkastus, turvallisuustaso, turvallisuuskäytännöt, tarkastuksen arviointi, itsearviointi

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Kaisa Kotisalo
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Helsinki, Finland

Contents

Abbreviations and definitions

Accident: An event that causes unintentional damage or injury (Harms-Ringdahl 2013).

Accident scenario: An undesirable event or a sequence of such events characterised by the loss of containment or the loss of physical integrity and the immediate or delayed consequences of such as occurrence. An accident scenario must be realistic and based on the quantity and properties of the substances in question, on the processes involved and the equipment used. A worst-case scenario is a situation in which everything that could go wrong does go wrong. UNECE (n.d.a); UNECE (n.d.b).

Assessment: The process, and result of systematically analysing and evaluating the hazards associated with sources and practices, and the associated protection and safety measures. (IAEA, 2006)

Audit: A systematic, independent and documented process for obtaining audit evidence and evaluating it objectively in order to determine the extent to which audit criteria are fulfilled (OHSAS 18001)

CCA: Committee of Competent Authorities. A forum for representatives of Member States and the Commission services. The CCA discusses and provides guidance on all issues concerning the implementation of the Seveso Directive.

CLP: Classification, Labelling and Packaging of substances and mixtures. The CLP Regulation aligns previous EU legislation on the classification, labelling and packaging of chemicals with the GHS. Its main objectives are to facilitate the international trade in chemicals and to maintain the existing level of protection of human health and the environment. The CLP Regulation entered into force on 20 January 2009.

Competent authority: The authority responsible for performing the duties laid down in the Seveso Directive (Seveso III Directive)

Establishment: The entire location under the control of an operator in which dangerous substances are present in one or more installations and in which common or related infrastructures or activities are included. Seveso establishments (both upper and lower tier) have obligations under the Seveso Directive. (Seveso III Directive)

GHS: The Globally Harmonized System for the classification and labelling of chemicals. The GHS is a United Nations system for identifying hazardous chemicals and informing users about the related hazards by placing standard symbols and phrases on packaging labels and using safety data sheets.

Human error (human failure): Unintended or intended actions which can be due to lack of attention, lapses of memory, rule-based errors, knowledge-based errors or violations of rules (Reason, 1990).

Incident: An unplanned sequence of events that has the potential for undesirable consequences (CCPS, 2011b)

Indicator: A selected, targeted and compressed variable that reflects public concerns and is intended for the use of decision-makers (Gudmunsson 1999 in Lähde, 2005)

Inspection: All actions, including site visits, checks of internal measures, systems and reports and follow-up documents, and any necessary follow-ups undertaken by or on behalf of the competent authority in order to check on and promote the compliance of establishments with the requirements of the Seveso Directive. (Seveso III Directive)

Lagging indicator: Any indicators measuring the outcomes of activities or events that have already occurred. Lagging indicators show when a desired safety outcome has failed, or has not been achieved. They focus on output and indicate how well a management system is performing. (HSE, 2006; Erikson, 2009; Dyreborg, 2009)

Leading indicator: Provides information for use in anticipating and developing organisational performance. Leading performance indicators focus on input and guide the reader how to achieve the main objective and improve performance. (Erikson, 2009; Dyreborg, 2009; Reiman and Pietikäinen, 2012).

Lower tier establishment: Lower tier establishments must establish a major-accident prevention policy (MAPP) which designs and guarantees a high level of protection for people and the environment using the appropriate means, structures and management systems (Seveso III Directive).

MAHB: The Major Accident Hazards Bureau. This addresses the disaster risks associated with hazardous industrial installations and contributes to the protection of citizens from the related threats, whether accidental or deliberate. This body developed and now manages the Major Accident Reporting System (eMARS)

Major accident: An occurrence such as a major emission, fire, or explosion resulting from uncontrolled developments during the operations of any establishment covered by the Seveso Directive, and posing a serious danger – either immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances – to human health or the environment, (Seveso III Directive)

MAPP: Major accident prevention policy. This is required from lower tier establishments in accordance with the Seveso Directive.

eMARS: The Major Accident Reporting System. The official reporting software for submitting accident reports to the European Commission in accordance with the Seveso Directive.

MJV: Mutual Joint Visits are for Seveso inspectors from across EU Member States. MJVs are intended to encourage the sharing and adoption of best practices for inspections.

Near-miss: An unplanned sequence of events that might have caused harm or loss if conditions were different, or if events were allowed to progress, but did not actually do so. (CCPS, 2011b)

Occupational (personal) health and safety: Conditions and factors that affect, the health and safety of employees or other workers (including temporary workers and contractor personnel), visitors, or any other person in the workplace. (OHSAS 18001)

Operator: Any natural or legal person who operates or controls an establishment or installation. (Seveso III Directive)

Process failure: Inability of a structure, system or component to function within acceptance criteria. (IAEA, 2006)

Process safety: The protection of people and property from episodic and catastrophic incidents that may result from unplanned or unexpected deviations in process conditions. Process safety includes the prevention of unintentional releases of chemicals, energy or other hazardous materials. (CCPS, 2011b; Maitland G., 2014)

Process safety indicator: The performance indicators for the measurement of process safety. Can be classified into leading–lagging, input–output, drive, monitor and outcome indicators.

Process safety management: A management system focused on the prevention of, preparedness for, mitigation of, response to, and restoration from catastrophic releases of chemicals or energy due to a process associated with a facility. (CCPS, 2011b)

Risk: The likelihood of a specific effect occurring within a specified period or in specified circumstances. (Seveso III Directive)

Root cause: Combinations of conditions and factors that underlie accidents or incidents. (Hollnagel 2004)

Safety: The quality of a system that allows it to function in a predetermined conditions with an acceptable minimum of accidental loss. (Roland H.E. & Moriarty B., 1983 in Kuusisto A., 2000)

Safety culture: The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation’s health and safety management. Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures. (HSE, 1993)

Safety management: The systematic control of worker performance, machine performance and physical environment. Such control includes both the prevention and correction of unsafe conditions and circumstances. (Heinrich et al., 1980)

Safety performance: A subsystem of organisational performance. The quality of safety-related work (effort made to achieve safety). (Nevhage B. & Lindahl H. 2008; Wu et al., 2008)

Seveso Directive: In this study, the term refers both to Seveso II Directive (96/82/EC) relating to the control of major-accident hazards involving dangerous substances and the Seveso III Directive (2012/18/EU), which replaced Seveso II in June 2015.

Tukes: The Finnish Safety and Chemicals Agency. The competent authority overseeing the implementation of the Seveso Directive in Finland.

TWGs: Technical Working Groups prepare guidelines on current topics on the surveillance of Deveso Directive. Such groups are established when needed and consist of representatives of Member States.

Upper tier establishment: Upper tier establishments are obliged to produce a safety report to demonstrate that a major-accident prevention policy and a safety management system for implementing it have been put into effect. (Seveso III Directive)

1 Introduction

1.1 Background

This study concerns itself with the assessment of process safety performance in Seveso establishments. The subject is approached from the perspective of the Finnish authority in question – the Finnish Safety and Chemicals Agency (Tukes) – and the study uses the same tools as Tukes to inspect and give scores to Seveso establishments. First, a study is used to compare the level of process safety procedures in three international companies located in seven European countries. The comparative study was conducted by Tukes between 2009 and 2011 (when the author was working in Tukes). Tukes used an assessment tool to compare the study establishments with one another. Observations were made on the need to develop assessment criteria and scoring tool used; accordingly, the study was followed up with the development of the current scoring system. This part of the study was conducted in cooperation with Tukes inspectors in 2012–2013.

Process safety performance is assessed by measuring safety management, which forms part of a company's overall management system. Much has been done at the highest level to facilitate safety management: legislation, regulations, guidance and auditable management systems have been introduced. Safety management requires good assessment tools in order to be effective. In different contexts, these can be termed e.g. safety metrics or (as in this study), safety indicators. The level of safety in industrial establishments is challenging to define or measure. Indicators that would give an overall picture of an establishment's safety levels are difficult to find.

A fairly high number of indicators are available for describing occupational safety. Fatal accidents provide a reasonably reliable means of comparing safety levels between countries and assessing the development of occupational safety with them. While the incidence rate is not a very reliable indicator, it can be used to compare companies or establishments with each other and for assessing the development within them. Moreover, standardised observation methods, such as Elmeri and TR-mittari, are fairly reliable methods for assessing company's or establishment's development and comparing companies within the same industry with one another. (Hämäläinen, 2010, p. 28-29; Laitinen & Päivärinta, 2010; Laitinen & Vuorinen & Simola, 2013, p. 313; Laitinen et al., 2013)

As indicated above, process safety means prevention of major accidents in process industry with a view to protecting people, the environment and property. Process safety is much more difficult to assess than occupational safety. This is partly due to a dilemma of a positive nature: major accidents are such rare events that they cannot be used to assess the level or development of process safety within a certain country or to assess the development of process safety in them. No reliable data exists on accidents or process errors which might have led to a major accident. Similarly, no standardised observation methods are available and the development and validation of such methods would be difficult in any case. In addition, in the absence of the proper validation of process safety audits, there is no way of determining whether achieving good results in an audit indicates a lower risk of a major accident than achieving poor results in the same process. The rarity of major accidents is another hindrance to assessing process safety. For the same reason, process safety inquiry methods have not been validated.

On occasions, the assumption has been made that good results in occupational safety are indicative of good results in process safety, and vice versa. Such thinking is supported by the assumption that the safety culture has a similar effect on both of these safety aspects. At any rate, like smaller process hazards and process errors, major occupational accidents seem to be the result of a more diverse range of events than fatalities or injuries. While there are certainly examples of good occupational safety results indicating good results in process safety, there are at least as many in which concentration on either of these aspects leads actors to neglect the other. In safety managements, attention must be therefore be paid to both occupational and process safety.

The Finnish Safety and Chemicals Agency, Tukes, supervises and promotes technical safety and conformity and chemical safety in Finland. Tukes' activities are aimed at protecting people, property and the environment from safety risks of any kind. Dangerous chemicals and gases are handled and stored in a range of plants and storage facilities e.g. chemical and explosives plants, oil refineries, pulp and paper plants, paint factories, power plants, and ports. Dangerous chemicals and gases include flammable liquids and gases and chemicals that pose a risk to health and the environment. In Finland, around 700 establishments house dangerous chemicals and gases which are supervised by Tukes. In addition to surveillance Tukes is active in national and international forms of co-operation and communication, such as guidance and lectures. Tukes participates in the development of legislation on chemical safety and in national and international co-operation on the issue. (Tukes, 2012a)

Among the actions they involve, Seveso inspections in Finland include giving scores to establishments for certain aspects of their operations; Tukes has been giving these scores since 2005, which are based on system that provides the inspected establishments with information on how well they have met the requirements of the Seveso Directive. The scores are also used as points of comparison: the establishments compare the results with earlier inspections (to establish whether they have improved) and compare some aspects of their safety work with others. In some cases, they also compare their scores with those of other establishments. In this study, the scores are used to compare inspected establishments with one another. By visiting and benchmarking establishments in other countries (via the case studies) Tukes is seeking to obtain information and knowledge on the safety methods and procedures applied elsewhere. These will help the organisation to become familiar with novel and different approaches and, in so doing, to implement best practices in Finland. Tukes hopes to use the results of the study as the basis of ideas on how to improve the safety practices examined in Seveso inspections in Finland.

1.2 Objectives and scope of the study

The aim of this study is to determine the suitability of Tukes' scoring system for comparing process safety between establishments located in Finland and to ascertain how well the system applies to comparing process safety in Finland with the level achieved in other EU countries (see the study). In this respect, it was found that the scoring system used in Finland required improvements. Another aim of this study is therefore to create an improved scoring system which would be more suitable and valid for use in Seveso inspections (development of scoring system).

This study also sets out to answer other questions. Part of the purpose of the visits was to collect information on actions by both the operators and authorities which have an effect on safety in establishments. Familiarisation with the establishments and companies was used to identify, it is also tried to find good practices which could be imported to Finland via Tukes' inspections and permits, for example. The study includes an assessment of the impact local authorities and legislation can have on safety levels. Another area of research involved identifying possible differences in process safety levels between Finnish establishments and those of other EU countries.

Prior to the study, it was assumed within Tukes that process safety in Seveso establishments in Finland was of average level compared to other EU countries. A further assumption was that safety levels within single companies were better in some EU countries than in Finland. Due to the lack of comparative data, Tukes wished to engage in a study and visit establishments abroad in order to establish whether there were any differences in process safety procedures. In particular, visits were planned to countries which have been EU Member States for some time. The Seveso Directive has been implemented for many years in such countries, long enough for its possible effects to feed through into the results of the study. Tukes was also interested in obtaining examples of good process safety procedures applied in foreign establishments. Its knowledge of process safety procedures would be deepened and it would emerge from the study in a position to develop process safety in Finland. Official procedures in other countries were another area of interest. Discussions of permits and inspections were included on visit agendas and local authorities were invited to participate.

During the analysis of the results of the study, some ideas were generated on how inspections in Finland could be improved by developing the scoring system. No other country is known to use such as system, which has received positive feedback from both from the inspectors who use it and the establishments being assessed by it. This gives little reason to believe that the basic principle underlying the system needs to be changed. However, in its current form the system lacks objectivity due to the lack of more detailed criteria. There can be differences in the scales used by different inspectors, in particular, can find it difficult to learn how to use the scoring system.

This study tries to answer to the following research questions

1. How well does the recent assessment tool of Tukes work when comparing levels of process safety between establishments?
2. Are the safety culture and safety procedures applied within each company similar, or do they vary between establishments in various countries? If there are differences, what kinds of differences are involved? What are the apparent reasons for such differences?
3. Do good practices exist in establishments abroad which could be imported to Finland?
4. What are the strengths and weaknesses of the current scoring system?
5. How might the objectivity of the scoring system be improved?
6. Would an improved scoring system be of help in easing the work-load involved in writing inspection reports?
7. Could an improved scoring system also be used as a self-assessment tool by operators?

2 Theoretical framework

This study focuses on both the technical and organisational aspects of process safety management. In this paragraph, the concepts relevant to the study are introduced.

The connection between the theoretical and empirical part of this study is presented in Figure 2.1. Topics in the theoretical framework can be divided into two sections: safety culture in Seveso establishments and demands on Seveso establishments. Safety culture comprises here different kinds of aspect which effect on the safety culture in the establishments. Demands on Seveso establishments comprises demands coming from legislation, standards and authorities. There are seven research questions answered in this study. The questions can be divided into two sections: testing of audit method and development of audit method. In the empirical part of this study the research questions are answered by visits to several Seveso establishments, comparing them to each other's and scoring the certain topics. After this, the new scoring method is developed and tested. In conclusion, there are suggestions for developing the method before taking it into use in Seveso inspections and as a self-assessment tool for the establishments.

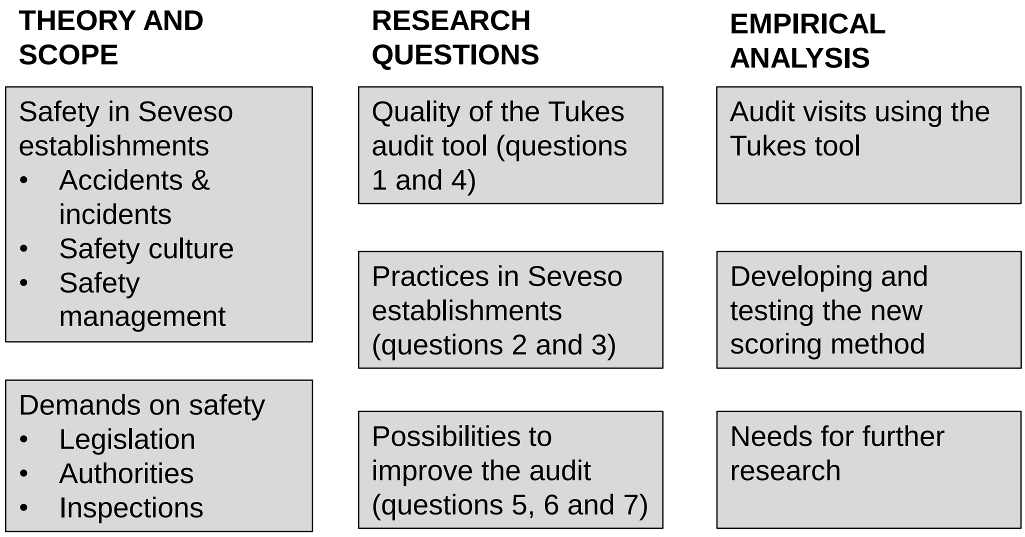

Figure 2.1: The connection between the theoretical and empirical part of the study

2.1 Accidents and incidents

For the purposes of this study an accident is an event that causes unintentional damage or injury (Harms-Ringdahl 2013) and an incident is an unplanned sequence of events that has the potential to end in undesirable consequences. A near-miss is an unplanned sequence of events that might have caused harm or loss if conditions were different or the events were allowed to unfold, but did not actually do so. (CCPS, 2011b) Process failures refer to the inability of a structure, system or component to function within the framework set by the acceptance criteria (IAEA, 2006).

Accidents can be regarded as the opposite of safety. Whenever an accident occurs, there is a need to find an explanation for what happened. In the Seveso Directive, major accidents have been defined as events such as a major emission, fire, or explosion resulting from uncontrolled developments during the course of the operation within any establishment covered by the Seveso Directive, and leading to a serious danger to human health and/or the environment, whether immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances (Seveso Directive). Fortunately, major accidents are rare. For this reason, safety levels in Seveso establishments in the different countries visited are difficult to assess by observing the number of major accidents. Although the public side of the European eMARS -register (The Major Accident Reporting System) provides information on major accidents and near misses, no information exists on the number of major accidents in specific countries. Statistics on occupational accidents are available which include work places of all kinds but statistics on Seveso establishments cannot be separated from those other locations.

However, such figures should be applied with caution. In every case, they are dependent on the definitions used during reporting and not all serious accidents are preceded by a succession of minor incidents and near misses. In addition, if minor accidents are managed effectively, while the rate of incidence of minor accidents decreases the major accident risk may stay the same or even slightly increase. (Hollnagel, 2004, p. 23-24; Reiman and Oedewald, 2008, p. 194; Manuele, 2013) This could be due to thewide spread of reasons for minor accidents and major accidents. Actions which are effective in reducing minor accidents can be ineffective in reducing major accidents. Furthermore, a focus on the prevention of minor incidents can lead to the situation where no attention whatsoever is paid to the prevention of major accidents. The pyramid model has been created on the basis of occupational health and safety accidents and its mechanisms do not correspond to e.g. environmental accidents. No evidence exists to suggest that minor accidents and major accidents share the same causes. This suggests that we have good reason to pay attention to the causes of major accidents which happen very rarely rather than concentrating solely on minor, frequently occurring accidents. (Manuele, 2003)

2.1.1 **Accident causation models**

Accident causation models, or accident models, are designed to answer questions on how and why an accident happened. As such, accident models form the basis of the investigation and analysis of accidents and their prevention (Leveson, 2004). Information on both technical and organisational aspects is required in order to ensure that accidents can be prevented. The results of accident analyses have changed a great deal since the 1960’s, when technological factors (technology and equipment) were named as the causes of accidents in around 70% of cases. Human factors became the number one cause in the 1970s, since when organisational reasons have taken first place. (Hollnagel, 2004, p. 45-46) Accident analyses now reveal that human factors are the dominant risks in the case of complex installations. Even what first appears to be a simple equipment failure can, in most cases, be traced to a prior human failure. In any case, it should be borne in mind that all components and items of equipment have a limited reliable lifetime and may fail for reasons related to engineering rather than human error. (Reason, 1990 p. 201)

Accidents and the reasons for them can be explained by a range of accident causation models. Key accident models in history (Hollnagel 2006) include Heinrich’s domino model and Reason’s Swiss cheese model, which are introduced in greater detail in this study. An accident model helps an organisation to determine which information to see and offer means of explaining the relationships between various factors. Even if good accident models are used, the causes of an accident are not easy to define. The value of finding the correct cause or explanation lies in the fact that this enables a systematic approach to preventing future accidents. (Hollnagel, 2004, p. 35; Hollnagel, 2006 p.

352) When discussing the causes of accidents, an attempt is often made to identify their root causes. Such a root cause can be defined as the combination of conditions and factors that underlie accidents or incidents (Hollnagel 2004 p. 51). In the field of nuclear safety, the root cause is defined as the fundamental cause of an initiating event, whereby the correction of the root cause would prevent the recurrence of such an event (IAEA, 2006).

Linear models are the simplest types of accident causation models and depict accidents as consequences of a sequence of events that occur in a specific order, where one factor leads to the next and further chain of factors leading up to the accident (Hollnagel 2004). A simple linear model of this kind is Heinrich's Domino Theory (formulated in 1931), which visualises an accident as a set of domino blocks lined up in such a manner that if one falls it will knock down those that follow (Heinrich et al., 1980). This can be seen in Figure 2.2. Five factors are involved in such a sequence:

- Social environment/ ancestry
- Fault of the person
- Unsafe acts, mechanical and physical hazards
- Accident
- Injury.

The social environment may lead to the development of undesirable character traits, or may interfere with education. Inheritance can lead to the passing on of recklessness, stubbornness, avariciousness and other undesirable features. Inherited or acquired faults can provide the impetus for committing unsafe acts (lingering in dangerous areas, careless starting of machines, and the removal of safeguards) or for the existence of mechanical or physical hazards (unprotected operating stations and insufficient light). To counter these factors, in accident prevention the focus should be on the middle of the sequence, which comprises an unsafe act or a mechanical or physical hazard. This model suggests that accidents could be prevented if one of the five factors were removed, thereby interrupting the knockdown effect. Heinrich focused on the human factor as the cause of most accidents. In his studies and analysis of 75,000 insurance claims 88% were caused by unsafe acts. (Heinrich 1959, p. 13, 19; Stranks 2007)

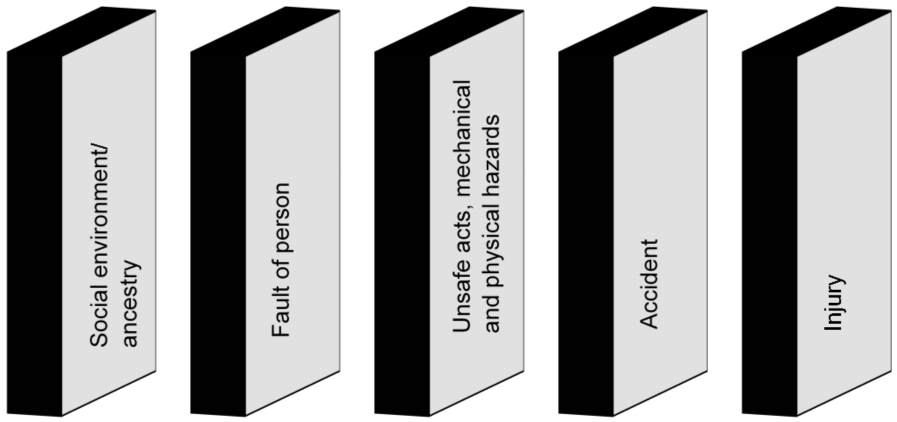

Figure 2.2: Domino model of accident causation (modified from Heinrich, 1959)

A complex linear model, Reason's Swiss cheese model (1990), emphasises the presence of two kinds of errors. In addition to active errors (based on the performance of 'front-line' operators) there are also latent errors (those whose activities are at a removed in terms of both time and space). This model views accidents as the result of unsafe acts by operators and of latent conditions (weakened barriers and defences). The model emphasises the importance of latent conditions and how they can lead to accidents when combined with active failures. The modified version of the Swiss cheese model can be seen in Figure 2.3. Reason did not specify the precise meaning of the various layers of cheese nor of the holes within them. (Reason, 1990; Hollnagel and Woods in Hollnagel, 2006 p. 11, 354)

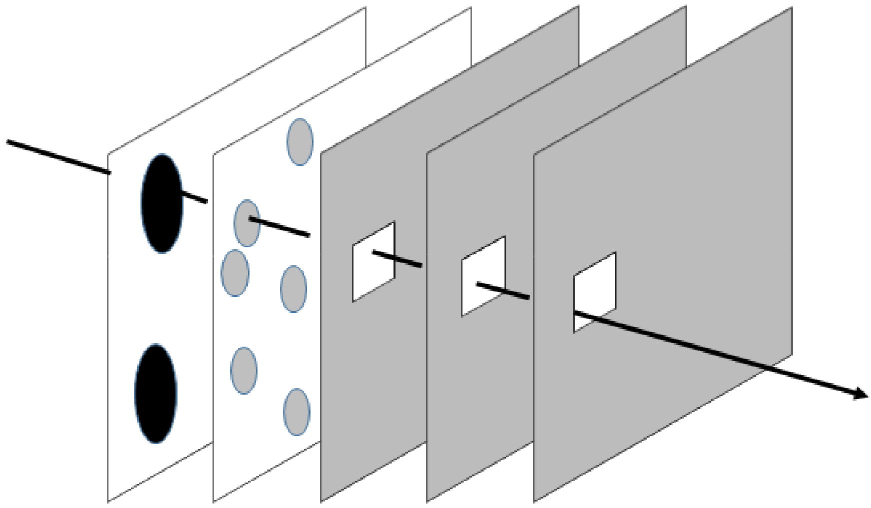

Figure 2.3: Swiss cheese model of accident causation (modified from Reason, 1990)

Different kinds of accident models are suitable for different situations. The choice of model should always be a conscious decision based on its advantages and disadvantages and the fact that models simplify the progress of an accident should always be borne in mind (Hollnagel, 2006 p. 353). Sklet (2004) compares an accident investigator to a technician; an accident investigator must choose the proper methods to be applied, by analysing a range of problem areas in the same way that a technician must choose the right tool for repairing a technical system.

A risk can be defined as the combination of the likelihood and likely consequences of a specified hazardous event (BS 8800, 1996). Risks cannot be completely eliminated from any set of operations, but all organisations must define the acceptable level of risks in their operations. Safety is often defined as the absence of danger of any harm or damage occurring (Steen, 1996). In addition, processes are regarded as safe if no accidents occur. However, this is a very narrow conception of safety. (Reiman and Oedewald, 2008, p. 218) An accident analysis should always be left open to interpretation if new facts appear or our understanding of the world around us improves (Hollnagel, 2004, p. 208).

Kletz has written about accident reports and how they often fail to identify all of the lessons that can be learned from them. Similar accidents tend to recur, often in the same factory or company. In many cases, the author of an accident report is unfamiliar with the history of the factory concerned and previous accidents in the same location. A risk arises in the situations where no one remembers why certain operating practices or equipment adopted due to an accident are present. (Kletz, 2009, p. 755-756; 1993, p. 4) After any accident, a proper investigation should be held and the related lessons learned in order to avoid the recurrence of similar incidents.

2.1.2 Occupational accidents

Risk levels are known to vary between different kinds of work. In addition, statistics are difficult to compare internationally due to differences in types of economic activity. Such differences can be based e.g. on natural resources, living standards, location or weather conditions. (TVL, 2014) Each time the different statistics are compared, one must bear in mind the possible differences in the ways the statistics were formulated. Sources can vary and the motivation to report incidents can differ depending e.g. on legislation and insurance. The statistics of Eurostat are based on reports from Member States. Two types of reporting systems are used in Europe: an insurance-based system and a system based on the legal obligations of the employer to report accidents. An insurance-based system is used in Greece, Belgium, Germany, Spain, Portugal, France, Italy, Luxemburg, Austria, the Czech Republic and Finland and is based on notifying the insurer of the accident. Such systems are maintained as a very reliable way of collecting data on accidents at work and the related rates of reporting are considered to be around 100%. In Bulgaria, Czech Republic, Denmark, Estonia, Ireland, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Romania, Slovakia, Sweden, Norway, Great Britain and the Netherlands the reporting system is based on the legal obligation of employers to notify the relevant national authorities of accidents (Universal Social Security System). In this case, the reporting rate tends to vary between 30% and 50%. For example, in Sweden the average reporting rate is 52% and in Norway it is between 25% and 100%. (Eurostat, 2014; 2001, p. 23–27; Hämäläinen, 2010, p. 28–29.)

Hämäläinen et al. (2006) have studied data on occupational accidents worldwide. They have also presented global estimates of occupational accidents in support of decision-making on safety measures. They found proper recording and notification systems to be lacking in developing countries in particular. In such cases, a problem arises because the resulting statistics, which may be unreliable, are used as a baseline for occupational safety work.

The concept of accident can differ greatly between countries as does the compensation system for accidents at work and occupational diseases. Statistical complications are also caused by differences in the follow-up of working hours and in the concept of an employee. (TVL, 2004)

Eurostat is the statistical office of the European Union. It has the task of providing the European Union with statistics at Europan level that enable comparisons between countries and regions. (Eurostat, 2012a) Eurostat also provides statistics on occupational health and safety. The statistics introduced in Figure 2.4 are derived from Eurostat, which publishes data in the most standardised form possible. Figure 2.4 shows the standardised incidence rates of fatal accidents at work in most European countries. Standardised incidence rate means that the incidence rates used for the calculation of the index are standardised by economic activity in European countries. This is done to eliminate differences due to different distributions of the national workforce across the high-risk and low-risk industries.

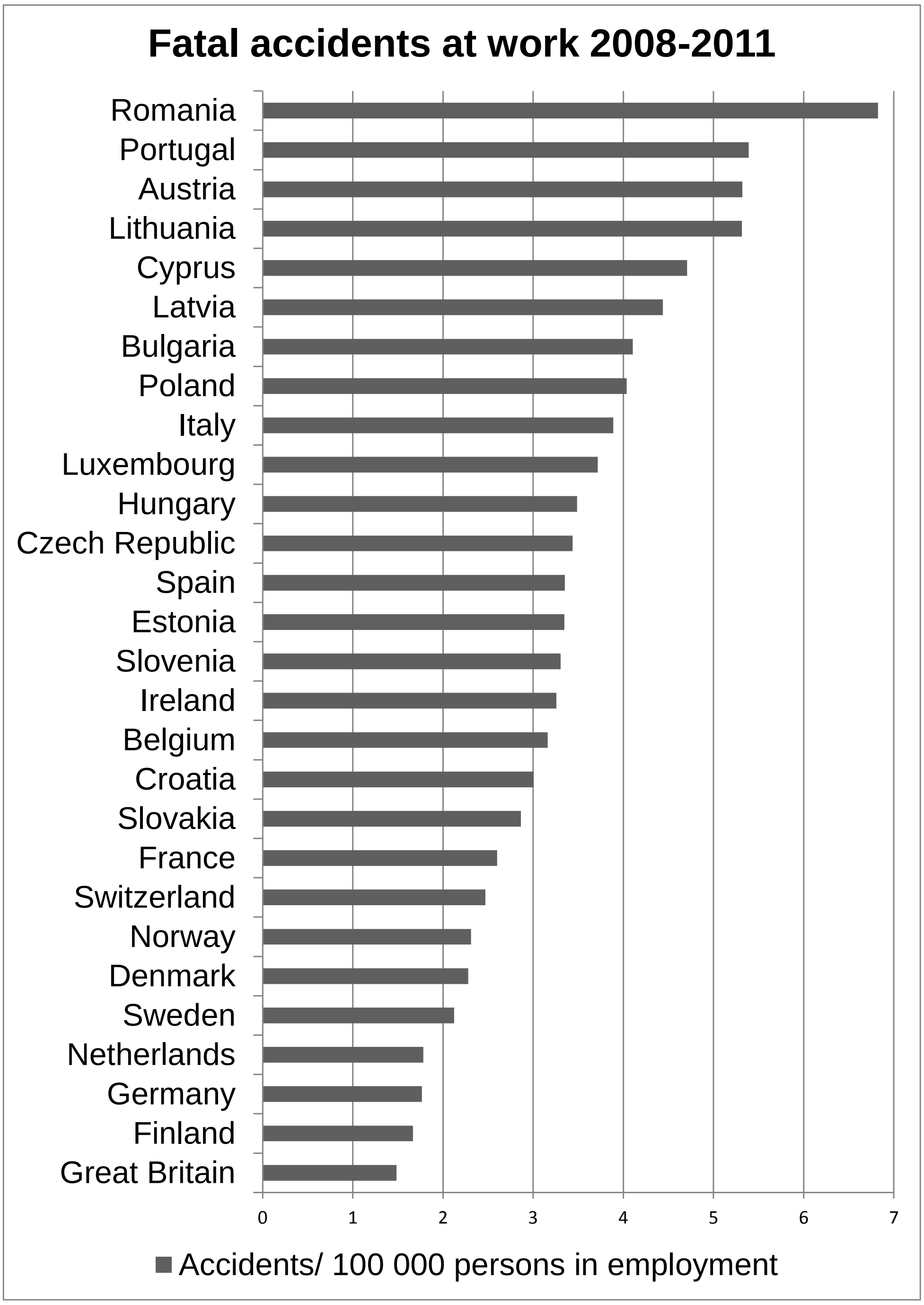

Figure 2.4: Fatal accidents at work in European countries in 2008–2011, standardised incidence rate. (Eurostat, 2014)

The statistics of fatal accidents are much more reliable than the statistics of other injury accidents. When comparing the number of fatal accidents, it can be seen that Romania, Lithuania, Portugal and Austria had the highest fatal accident rates (more than 4 accidents per 100,000 persons in employment) between 2008 and 2011. Safety audits of this research were carried out in Belgium, Finland, France, Germany, Great Britain, the Netherlands and in Sweden. Of the visited countries, all performed well according to the statistics on fatal accidents i.e. the number of fatal accidents was low. Belgium had the highest fatal accident rate (2.4), while the lowest in Europe were recorded in Great Britain, Finland, Germany, the Netherlands and Sweden. Of the countries visited for the study, the Netherlands had the lowest fatal accident rate (1.0).

2.1.3 Major accidents

Following a series of major accidents in the 1970s, the Member States of the EU acknowledged the need for international action to prevent such accidents. The Seveso Directive was adopted in 1982 (82/501/EEC) for just this purpose. The few major accidents that have occurred since have led to amendments that have broadened the scope of the first Directive. The second Seveso Directive (Directive 96/82/EC) altered the scope of the Directive from identifying a list of named substances and regulating individual technical installations to focusing on the management systems of entire establishments. Again, in the wake of a small series of accidents (at Enschede, Baia Mare and Toulouse) a further amendment came into force in 2003. (Versluis et al., 2010, p.627–628) Major industrial accidents that have led to the amendment of the Seveso Directive are shown in Table 2.1.

Table 2.1: Overview of major industrial accidents leading to amendments of the Seveso Directive since the 1970s. (Versluis et al., 2010, p. 628)

Country/ location	**Year**	**Episode/ chemical involved**	**Consequences**
UK/ Flixborough	1974	Fuel air explosion	28 fatalities, >50 injured, property damage
Netherlands/ Beek	1975	Vapour cloud explosion (Ethylene)	14 fatalities, 109 injured

Country/ location	**Year**	**Episode/ chemical involved**	**Consequences**
Italy/ Seveso	1976	Vapour cloud explosion (Dioxin)	No fatalities. Injuries and damage to the environment and animal life. Long term adverse health effects.
India/ Bhopal	1984	Methyl Isocyanate	Estimated fatalities between 3,500 and 18,000, >500,000 injured, major property damage
Switzerland/ Basel	1986	Fire at a chemical plant for agricultural chemicals	No fatalities, damage to natural resources and property
Netherlands/ Enschede	2000	Fireworks	23 fatalities, >1,000 injured, property damage
Romania/ Baia Mare	2000	Cyanide	No fatalities, water supply affected, major environmental consequences
France/ Toulouse	2001	Ammonium Nitrate	29 fatalities, >2,000 injured, property damage

In EU, certain criteria oblige the competent authorities to report accidents to the EU's eMARS register. The criteria are as follows: injuries to persons, damage to property, direct damage to the environment, or lessons learned. The Seveso Directive lists the criteria requiring the notification of an accident to the Commission based on the substances involved or any injury caused to persons and damage to real estate or the environment:

- Involving substances
  - All fires or explosions or accidental discharges of a dangerous substance involving at least 5 % of the qualifying quantity listed in column 3 of Annex I of the Seveso II Directive.
- Personal injury or property damage
  - An accident directly involving a dangerous substance and giving rise to one of the following events:
    - a death
    - 6 persons injured within the establishment and hospitalised
    - 1 person outside the establishment hospitalised
    - housing outside the establishment being damaged and become unusable
    - the evacuation or confinement of persons for more than 2 hours (persons x the number of hours must equal at least 500)
    - the interruption of drinking water, electricity, gas or telephone services for more than 2 hours (persons x number of hours must equal at least 1,000)
- Immediate damage to the environment
  - permanent or long-term damage to terrestrial habitats
    - ≥0.5 ha of a habitat of environmental or conservation importance that is protected by legislation
    - ≥10 ha of a more extensive habitat
  - significant or long-term damage to freshwater and marine habitats
    - ≥10 km of a river or canal
    - ≥1 ha of a lake or pond
    - ≥2 ha of a delta
    - ≥2 ha of a coastline or open sea
  - significant damage to an aquifer or underground water
    - ≥1 ha
- Damage to property
  - in an establishment ≥ MEUR 2
  - outside the establishment ≥MEUR 0.5
- Cross-border damage
  - Any accident directly involving a dangerous substance and giving rise to effects outside the territory of the Member State concerned.
- Accidents or near misses which Member States regard as being of particular technical interest in the future prevention of major accidents and limiting their consequences and which do not meet the quantitative criteria above.

The yearly average for reported major accidents is around 30. The number of accidents reported in the eMARS register can be seen in Figure 2.5. In the eMARS register, the main accident types are chemical release, fire or explosion. (van Wijk, 2011, p. 16, 39). As it can be seen in Table 2.2, the average number of major accidents in EU is 2.7

accidents per 1,000 establishments per year. The table also shows, that the average in Finland is 1.8 major accidents per 1,000 establishments per year, which supports the hypothesis of Tukes that the level of process safety in Finnish establishments is average in comparison to EU countries in general. The average number of accidents reported to eMARS is 28 and the 95% confidence interval is 23 to 33. In 2002, the number of accidents was above the upper confidence level and in 2009 it was below the lower confidence level. Based on the figure, it can be seen that the number of major accidents is decreasing. Also the cumulative 3-year average support this view.

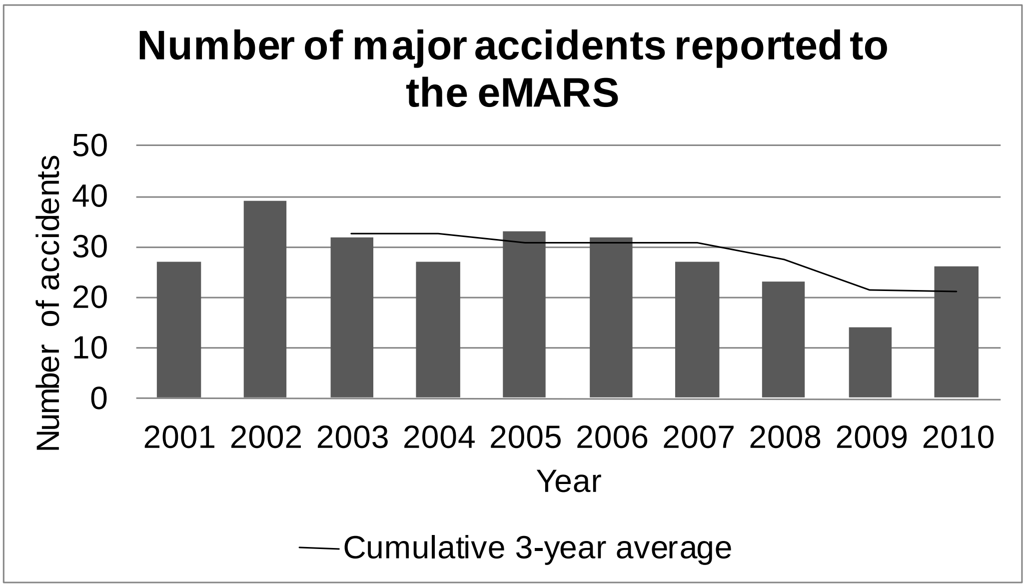

Figure 2.5: Major accidents reported to the EU's eMARS register. (van Wijk, 2011, p.6)

Table 2.2: Accidents reported to the eMARS register in all Member States and in Finland. (van Wijk, 2011, p. 6; Sjölund et al., 2001; Tihinen et al., 2002; Aarnivuo et al., 2004; Kotisalo et al., 2009; Tihinen and Ijäs, 2011; Heinimaa, 2015, p. 10)

	EU Member States	**Finland**
Number of reported accidents/ year	28	0,5
Number of Seveso establishments	10 300	280
Number of reported accidents/ year/ 1,000 establishments	2.7	1.8

Accidents which have been reported to the eMARS register from Finland in 2001-2014 are shown in Table 2.3. A total of 9 cases have been reported during that period. The largest industrial accident in Finland before then was the explosion at the Lapua cartridge factory in 1976, in which 40 employees were killed and dozens of people were injured. (Yleisradio, 2006)

Table 2.3: Accidents reported to the eMARS register by Finland in 2001-2014. (Sjölund et al., 2001; Tihinen et al., 2002; Aarnivuo et al., 2004; Kotisalo et al., 2009; Tihinen and Ijäs, 2011; Talvitie, 2011; Penttinen and Ijäs 2012; Levä et al., 2013;Tukes, 2014a; Nissilä et al., 2014; Tukes, 2015c)

Company	**Year**	**Episode/ chemical involved**	**Consequences**
Dynea Finland Oy	2001	Leakage of phenol	Contamination of soil
Nexplo Vihtavuori Oy	2002	Explosion during gunpowder production	One fatality, property damage
AvestaPolarit Stainless Oy	2003	Fire in the oxygen pipeline of a steel mill's smeltery	3 fatalities, property damage
Abloy Oy	2009	Fire in a surface treatment plant	Major property damage
Arizona Chemical Oy	2010	Explosion of a tank during maintenance work	One fatality, one case of serious injury, property damage
Arizona Chemical Oy	2011	Exposure to turpentine	One fatality
Talvivaara Sotkamo Oy	2012	Exposure to hydrogen sulphide	One fatality
Forcit Oy Ab Vihtavuori	2013	Risk of explosion and fire: chemical reaction in a waste container	-
Fortum Power and Heat Oy	2014	Explosion in the pyrolysis plant	Three injured, one seriously

It is important to investigate the reasons for and factors behind such accidents for the purposes of accident prevention and safety improvement in the process industry. Kidam and Hurme (2013, p. 168–169) have analysed accidents in the chemical process industry (364 accidents) collecting data from the Failure Knowledge Database of the Science

Technology Agency of Japan. Accident reports were analysed in order to identify the factors and root causes that led to the accidents – i.e. both the main and other contributors. Contributors were classified into three categories:

- human and organisational (management, organizational and human failures related to plant operation),
- technical (design errors such as poor layout, wrong selection of construction material, operator errors induced by technical factors etc.) and
- external factors.

On average, a total of 2.2 contributors identified per accident, totalling 806 contributors.

In most cases, accidents occur due to multiple causes. A study by Kidam and Hurme (2013, p. 169, 174) analysed the main contributors and subcontributors to accidents. The main contributor was considered to be the main factor directly initiating or triggering the accident. While subcontributors also play a significant role in accidents, their role is smaller than that of the main contributors. In the study it was found that nearly all accidents have causes of several types. 79% of all contributors to accidents were technical issues, 19% human and organisational causes and 2% were external causes. Kidam and Hurme state that the results correspond fairly well with average figures (technical issues 73%) published earlier (Drogaris, 1993; Nivolianitou et al., 2006; Sales et al., 2007) based on the same classification.

In the establishments supervised by Tukes, there were 32 chemical accidents (handling or storing dangerous chemicals has caused injuries, damage to property > 30,000€ or harming the environment) in 2014. These accidents are reported to the accident database of Tukes (VARO). In 78% of these accidents, at least one technical contributor numbered among the causes. In 41% of accidents, human activities were found to have been either direct or indirect contributors. (Tukes, 2015b) These results also correspond well with the results of Kidam and Hurme. Among the organisational reasons, the main causes were deficiencies in the identification and assessment of hazards (Tukes, 2015b).

The most common main contributors to accidents were human and organisational aspects (16%), process contamination (14%), flow-related aspects (13%), heat transfer (12%), layout (10%) and fabrication/ construction/ installation (10%). The most frequent contributors derived from all contributors to accidents were found to be the same as the most frequent causes identified among the main contributors. (Kidam and Hurme, 2013)

One of Tukes' goals is to induce a notable reduction in the annual number of accidents in the process industry from the average level for the years 1995–1999 (44 cases) by 2014. In 2014, this goal was duly achieved: the number of accidents in the process industry amounted to 36 cases. (Tukes, 2015a) The number of accidents in the Finnish process industry in 2000–2014 can be seen in Figure 2.6 while the average number of such accidents is 39. The 95% confidence interval is 35 to 42. Based on the figure, it is impossible to say whether the number of accidents in Finland's process industry is decreasing or increasing. However, the second half of the figure shows that, over a period of three years, the number of accidents has been below the lower confidence level. This indicates that the number of accidents is decreasing. Also the cumulative 3-year average support this view.

Figure 2.6: Accidents in the process industry (including mining) in Finland in 2000-2014. (Tukes, 2015a, p. 3; Tukes, 2010, p. 6; Heinsalmi and Mattila, 2007, p. 21)

Figure 2.7 shows the number of accidents occurring in different branches of the process industry. In 2007–2013 the highest number of accidents occurred in petrochemical and oil refining operations (50 accidents). Almost as many accidents occurred in wood processing (47 accidents). The third highest number occurred in other sectors, including storages, building materials and industrial plants of other kinds.

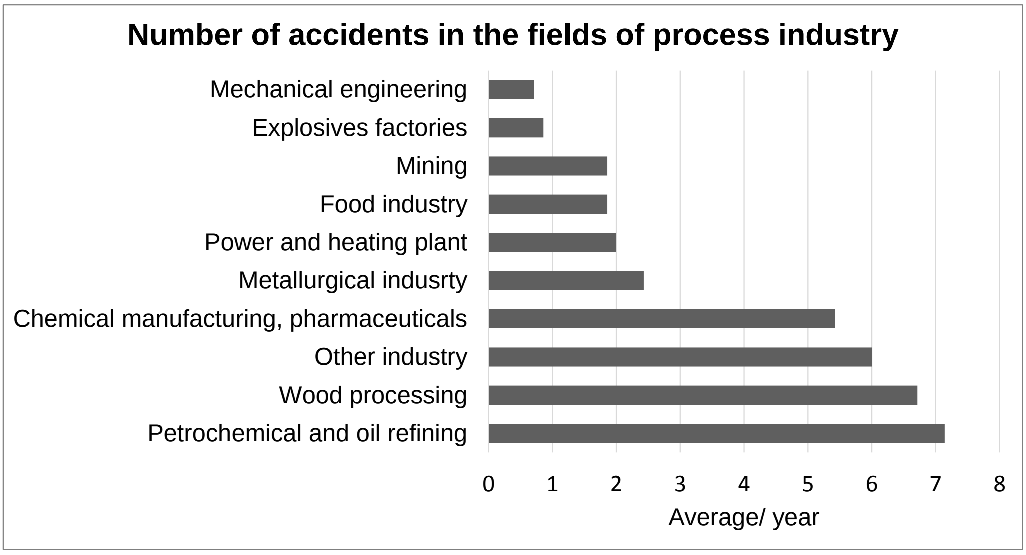

Figure 2.7: Average number of accidents in branches of the process industry in 2007–2013 in Finland. (Heinsalmi and Mattila, 2008, p. 20; Mattila, 2009, p. 20; Tukes, 2010, p. 6; Tukes, 2011a, p. 6; Tukes, 2012b, p. 6; Tukes, 2013a, p. 6; Tukes, 2014b)

Tukes supervises establishments which store or handle dangerous chemicals. In the ten-year period of 2005–2014 there were 295 accidents in such establishments. In Figure 2.8 there is shown the types of those accidents. Of all accidents, 73% were due to leaks, while fires and injuries each accounted for 10% of the accidents. Explosions (5%) and equipment damage (2%) were recorded in addition. These accidents include those that led to injuries, property damage valued at over € 30,000, or damage to the environment. (Tukes, 2015b)

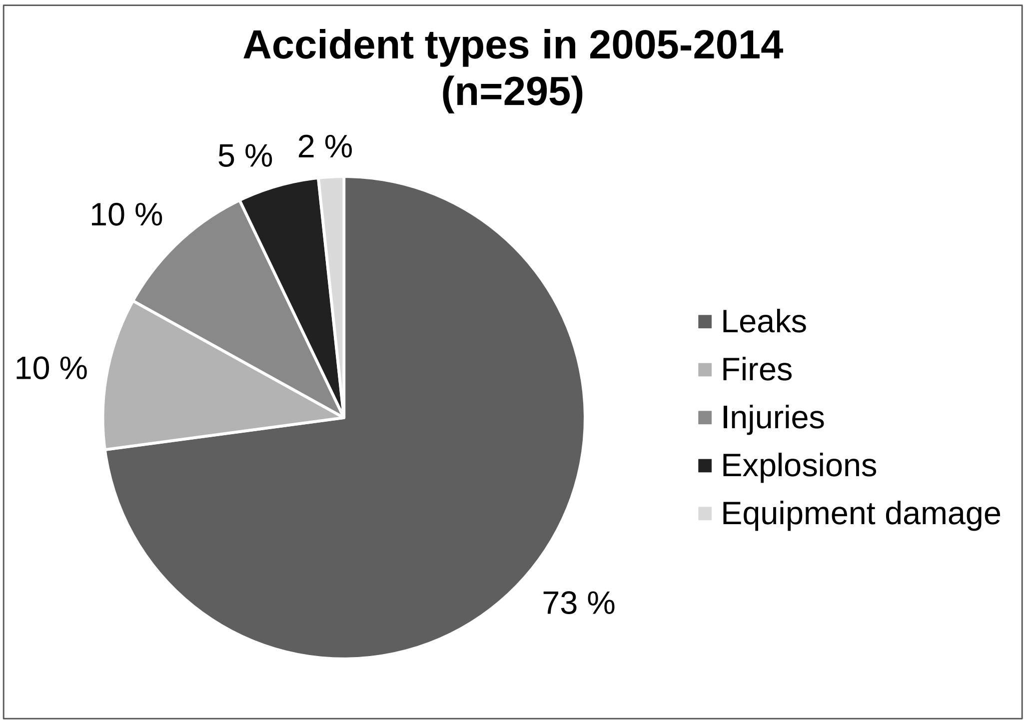

Figure 2.8: Accident types in establishments under surveillance by Tukes due to the handling or storage of dangerous chemicals in Finland in 2005–2014. (Tukes, 2010b; Tukes, 2015b)

Three kinds of establishments are under surveillance by Tukes: two referred to by the Seveso Directive (upper tier and lower tier) and one defined in Finland's national legislation. Upper tier establishments are obliged to draw up a safety report and lower tier establishments must have a major accident prevention policy (MAPP). Other establishments under Tukes' surveillance must also apply for a permit and are subject to periodical inspections.

Table 2.4 shows the segmentation of establishments in Finland and of accidents that have occurred. A total of 70% of accidents occurred in just 19% of establishments (upper tier establishments). This makes the number of accidents in upper tier establishments almost 9 times higher than in lower tier establishments and almost 11 times higher than in other establishments under Tukes' surveillance. While this may indicate the higher risk in upper tier establishments, it may also tell us something about the level of activeness in reporting accidents to the authorities. Upper tier establishments often belong to larger companies which make more comprehensive use of safety management systems than lower tier or other establishments.

Table 2.4: Accidents in different types of establishments in 2012–2014 (Tukes, 2013b; Tukes 2014b; Tukes 2015b).

	Proportion of establishments, % (average 705 establishments/ year)	Proportion of accidents, % (n=85)
Upper tier	18	56
Lower tier	22	22
Other establishments under Tukes' surveillance [1]	60	21

[1] Other establishments under Tukes' surveillance have lower amounts of dangerous chemicals and are therefore subject to fewer requirements than Seveso establishments.

As can be seen in Figure 2.9, more than a third (37%) of accidents occurred during normal operations, while more than fifth (22%) occurred during loading or unloading. The third significant phase tends to have been repair and maintenance work (13%). Other phases with a proneness to accidents included start-ups and shutdowns, process errors, energy production, other chemical handling and storing. (Tukes, 2011b; Tukes, 2012c; Tukes, 2013b; Tukes, 2014b; Tukes, 2015b)

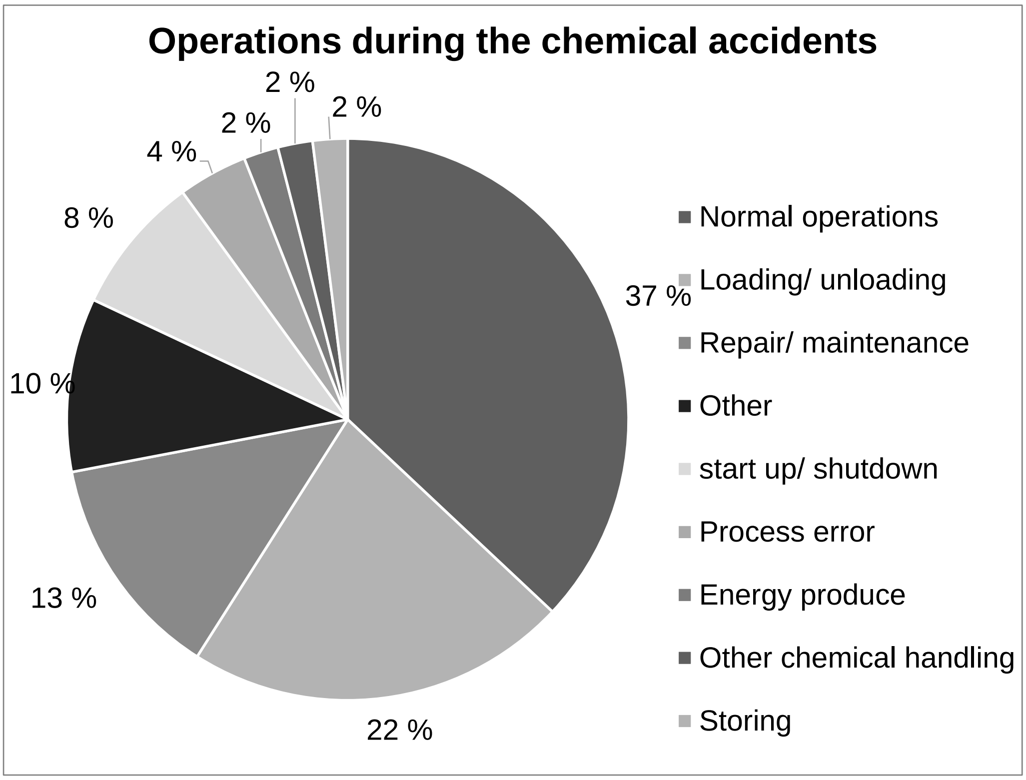

Figure 2.9: Phases of operations during which accidents occurred in establishments under Tukes surveillance in 2010–2014. Other chemical handling includes e.g. the transfer of chemicals from one container to another, the dilution of chemicals, and the taking of samples from chemicals. (Tukes, 2011b; Tukes, 2012c; Tukes, 2013b; Tukes, 2014b; Tukes, 2015b)

2.2 Safety culture

The concept of a safety culture was developed in the report on the Chernobyl nuclear disaster in 1986. According to the IAEA (International Atomic Energy Agency), a safety culture has two major components: a framework determined by organisational policy and managerial action, and the response of individuals in terms of working within and benefiting from the framework. The success of the safety culture depends on the level of commitment and competence provided both in terms of policy and managerial context and by the individuals themselves. (IAEA 1991) Since the 1980s, the safety culture concept has spread from atomic energy into other fields of industry. The nuclear safety industry followed by other safety critical sectors in requiring a highly developed safety culture that must be demonstrated by the companies concerned (Reiman and Oedewald, 2008, p. 121-122).

The safety culture approach taken by the HSE (Health and Safety Executive of Great Britain) highlights cooperation, communication and competencies. The HSE (1993) gives the following definition of a safety culture:

The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organization's health and safety management. Organizations with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures.

Attitudes and actions are often emphasised in definitions of safety cultures (Lanne, 2007, p. 33). Different kinds of approaches are taken to safety cultures; some researchers believe that every organisation has a safety culture of some kind, which can be described as strong or weak, positive or negative. Others are of the view that only an organisation with a strong commitment to safety can be said to have a safety culture. (Hopkins, 2006)

A safety culture is part of an organisational culture; organisational cultures are generally assumed to have a major effect on safety cultures. An organisational culture defines the way in which an organisation reacts to safety and the level of safety which the management deems acceptable. Safety cultures cannot be developed in isolation from other aspects of an organisation. In their study on safety cultures, Booth and Lee, 1995; Manuele, 1997 in Levä, 2003, 28; Simola, 2005, p. 40) Frazier et al., 2013) concluded in their study on safety culture that the construction of a positive safety culture is not easy or universal. In every case, it depends on the goals and the resources of an organisation. A common factor is the need to include employees in the process.

In the opinion of Reiman and Oedewald (2008, p. 129), a good safety culture is about understanding the dangers associated with various actions, being aware of the risks involved, caring about safety, taking responsibility and trying to ensure that risks are managed. In complex safety critical organisations, the following factors are emphasised: avoiding oversimplification, reflecting on and questioning habits and routines, bearing risks and the possibility of failure in mind dealing with unforeseen issues, reviewing issues as part of the big picture and decision-making based on knowledge rather than organisational status. The requirements of the work in question and phenomena associated with the operations of the organisation concerned must also be understood.

The safety climate is often mentioned in research on safety cultures. Indeed, 'safety culture' and 'safety climate' are frequently used as synonyms, or in some cases culture is clearly distinguished from climate, whereas in others the difference between the two is left undefined. Studies measuring the safety climate also measure aspects of the safety culture and vice-versa. (Reiman and Oedewald, 2008, p. 126) Guldenmund (2000, p. 247) has explored the nature of safety cultures by reviewing several theories and studies on the topic. A literature review on safety cultures and safety climates has shown that the relationship between them is unclear and that confusion exists about the cause, content and consequences of safety cultures and climates. No satisfying models of the relation between safety culture and safety climate could be found in the literature.

The safety culture should be measured for the following purposes:

- clarifying what kind of safety culture an organisation has
- understanding in what direction should a safety culture be developed and
- learning how effective previous actions have been in enhancing the safety culture (Ruuhilehto and Vilppola, 2000, p. 46).

Indicators of the extent of safety cultures include the management's commitment to safety, as well as safety training and motivation, safety committees and safety rules, record keeping on accidents, sufficient inspection and communication, adequate operation and maintenance procedures, well-designed and functioning technical equipment and good housekeeping. (Grote and Künzler, 2000) Once the employees' execution of a safety culture has been measured, the results must be communicated to demonstrate that senior management views a good safety performance as a priority. Ruuhilehto and Vilppola have shown that the execution of a safety management system is one of the indicators of a safety culture (2000, p. 50).

Smith (2012) has written that the development of a safety culture is unique to the individual organisations in question. The culture within an organisation can be changed – safety culture is a concept of practical value which not only reduces the risks of injury, but also drives efficiency and productivity in working towards a healthy working environment and successful business.

2.3 Safety management

Many definitions of safety management can be found in the literature. Safety management depends greatly on the beliefs and assumptions made by the management and personnel of an organisation. The safety management focus is often on the possible ways in which things can go wrong. Negative events, such as the numbers of accidents, breakdowns, adverse events and process leaks are frequently applied as safety indicators. (Reiman T. et al., 2015)

Lanne (2007, p. 28-29) has arrived at a very broad definition of safety management; safety management involves taking account safety in strategic decisions and at operational level. Many researchers (Booth and Lee, 1995; Visser, 1996; Petersen, 2000 in Levä, 2003, p. 35) have defined safety management as the protection of people, the environment and property and the systematic development of safety. Safety management aims at the prevention and limitation of accidents and damaging events within an organisation. The ideological goal of safety management is therefore the controlled mitigation of various shortcomings affecting people, the environment and assets. Organisations often view safety management as a process which supports their business operations. (Lanne, 2007, p. 29)

In a wide literature review, Levä (2003, p. 35-36) has listed the factors that seem part of good safety management. Such factors concern safety goals and responsibilities, management commitment, danger identification, proactive maintenance, safety measurement, accident investigations and learning from accidents. Hämäläinen (2010) has reached similar conclusions on successful occupational health and safety management. She has divided the relevant factors into three categories: safety policy, organisation and methods. (Hämäläinen and Anttila, 2009 in Hämäläinen, 2010, p. 26)

Levä (2003) studied the functionality of safety management systems in installations risk of a major accident in Finland. The results revealed the major problem areas, which are as follows: subcontractors' safety issues, maintenance in practice, the control of changes and the measurement of safety, internal audits and management reviews of hazardous chemicals. These problems seemed to be due to strategic weaknesses in management systems. The research material was partly collected during Tukes' inspections of the establishments in question. Simola's (2005) study showed that results are achieved by attending thoroughly to the improvement of safety matters. His model brings together the basic elements of safety management for which line supervisors are responsible: risk assessment of one's own work, advanced accident and near-accident investigation, shop floor safety meetings and advanced safety inspection. The model also clarifies the role of line supervisors as safety leaders.

In their study, Knegtering & Pasman (2009) discuss the safety of process industries in the 21st century. It seems that contemporary accidents are almost always the result of a combination of organisational issues, lack of competencies and technical failure. Safety is now being affected by a multitude of changes: reductions of labour and staff, increasing turnover, the growing complexity of process installations, the continuous development of sophisticated designs of process control and accident prevention technology. The process industry needs new kinds of process safety management to cope with such changes.

A safety management system in an organisation is formed from planned activities for controlling health and safety (Kuusisto, 2000, p. 33). Safety should be managed like any other company function. Management should manage the safety effect by setting achievable goals, planning, organising, and controlling in order to achieve such goals (Petersen, 2001, p. 15). The development and study of safety management systems has been a key theme in recent decades. In occupational health and safety management, the most commonly used standardised system in Finland is OHSAS 18001. This is based on the British standard BS 8800 and has the same kind of structure as the environmental management system ISO 14001. (Reiman and Oedewald, 2008, p. 43, 63) The Seveso Directive also includes requirements for a safety management system in Seveso establishments (Directive 96/82/EU).

Table 2.6 makes a comparison between the content of the Seveso Directive and the OHSAS 18001 standard. There is no single, correct way of achieving safety in every organisation. However, the criteria exist for an effective safety management system: supervisors are required to perform up to a certain standard, middle management must be involved, senior management must show their commitment and employees must participate. The system must also be flexible and applied with a positive attitude. (Petersen, 2001, p. 15–19)

Safety management is often divided between two perspectives: process safety management and occupational health and safety management. Many aspects are common to both perspectives, but many also differ. The focus of both process safety and occupational safety is on protecting people in the workplace and protecting against 'ordinary' accidents. Protecting against catastrophic accidents is a focus of process safety, but it can also be considered as a focus of occupational safety. Process safety focuses also on protecting people outside workplace and property and the environment. On the other hand, process safety does not focus on protecting against occupational diseases, even if they are caused by chemicals. That is one of focuses of occupational safety.

2.4 Resilience engineering

Resilience is commonly defined by dictionaries as the ability to recover quickly from difficulties such as illness, change or misfortune. Hollnagel (2006, p. 16) has defined resilience as the ability of a system or organisation to react to and recover from disturbances at an early stage, resulting in a minimal effect on dynamic stability. According to Dekker (2005, p. 45) *organisational resilience is not a property, it is a capability: the capability to recognise the boundaries of safe operations, a capability to steer back from them in a controlled manner, a capability to recover from a loss of control if it does occur.*

Resilience engineering can be viewed as a new approach to safety, which challenges and complements old ways of approaching the issue. The traditional approach is based on correcting deficiencies and emphasises the registration of errors and the calculation of probabilities. In resilience engineering, an organisation’s ability to create new sustainable and flexible processes is expanded (Uusitalo et al., 2009, p. 9). We can also question whether resilience is a new phenomenon. Hale and Heijer (in Hollnagel, 2006, p. 40) point out that we already have terms referring to resilience, such as high reliability organisations and organisations with an excellent safety culture. If, by resilience, we mean avoiding accidents in addition to surviving them, then we can conclude that safety is concerned.

Controlling safety requires that a safety system include anticipation, monitoring and the ability to respond. The system must be continuously alert and ready to react. According to the definition of resilience engineering safety is what the socio-technical system does rather than the kind of system it is or the elements contained within it. Safety is not a feature of a system that remains stable once created. On the contrary, the performance level of a system is a good way of characterising safety. (Uusitalo et al., 2009, p. 4-7)

If resilience meant no more than overcoming adversity, it would not be useful in improving safety. Such a concept can only be useful if the definition is expanded to cover the ability to act, to establish safety and to avoid accidents in difficult conditions. (Uusitalo et al., 2009, p. 8) Resilience can also be developed into an overall theory of safety and risk management, rather than just a theory of accidents. Safety is therefore viewed as something an organisation does rather than has. According to Hollnagel and Woods (Hollnagel, 2006, p. 347) resilience cannot be measured but an organisation's potential for resilience can be.

Resilient systems require three qualities in order for their users to retain control over safety:

- anticipation, knowing what to expect
- attention, knowing what to look for, and
- response, knowing what to do.

Resilient systems must also be updated with knowledge, competencies and resources based on learning from successes and failures. (Hollnagel and Woods in Hollnagel, 2006, p. 350)

2.5 Safety audits and inspections

2.5.1 Audits

In OHSAS 18001, an audit is defined as a systematic and independent examination to determine whether a company’s activities comply with planned arrangements and whether such arrangements are being implemented effectively and are suitable for achieving the objectives in question (OHSAS 18001, 2007). The effectiveness and adequacy of a safety management system should be regularly assessed. Different kinds of assessment methods can be used, the most common being the measurement of safety performance (safety indicators), safety audits and management reviews. Safety audits have two goals: they should verify that the minimum legal requirements are being met and that current safety efforts are effective and sufficient. (Glendon, 1995 in Kuusisto, 2000, p. 20)

An audit is a systematic review of operations and practices and is intended to ensure that the relevant requirements are being met. An audit is conducted at either managerial or corporate level. A safety audit is a structured, methodical assessment and evaluation of how workplace activities affect safety and health. The goal of a safety audit is to ensure a safe workplace by striving to eliminate unsafe practices and hazards that lead to injuries and accidents. An audit consists of the collection and evaluation of data. A safety audit identifies both the strengths and weaknesses of a system and should show an organisation where improvements can and should be implemented. (The American Chemical Society, 2000).

An audit should include personnel interviews, documentation reviews and visits to the workplace. The audit of a safety management system can begin and end with an analysis of what is included in the paperwork, but this will say little about how the system is being implemented in the field. Such an analysis identifies what an organisation should be doing to protect its workers, the public and the environment from harm, but it does not reveal what is actually happening at the worksite, whether people and the environment are being protected, and whether or not adverse events are occurring. (Kuusisto, 2000, p. 20; Mearns et al., 2003) Auditing is a typical organisational assessment activity. An organisational assessment is a process used for measuring the effectiveness of an organisation from the behavioural or social-system perspective. (Lawler et al., 1980 in Kuusisto, 2000, p. 57)

A safety audit can be performed either internally or externally. In internal audits, a performance is reviewed by a company's own personnel, while in external audits such an assessment is performed by a trained expert from outside the organisation. (Kuusisto, 2000, p. 59) There are also peer reviews, whereby audits are conducted by experts from a similar organisation. (Reiman and Oedewald, 2008, p. 343) Use of an external auditor is advantageous since such a person is not personally responsible for safety activities within the organisation. On the other hand, the company's own personnel are probably more knowledgeable of the safety activities being practiced within the company. (Kuusisto, 2000, p. 153)

The results should be similar even if the audit is being conducted by different auditors. Auditor training, auditor performance comparisons, reviews of audit reports and rotation of auditors between audit teams can be used to improve consistency among auditors. (ISO 10011-3, 1991)

Tools for safety audits usually include a list of the safety activities to be assessed and the criteria applied to evaluation. These activities are typically grouped under headings such as organisation, risk control or reporting. (Kuusisto, 2000, p. 64) Most safety audit methods include a scoring system and criteria for allocating the scores. In a safety audit special attention should be paid to the preparation of the audit, and to the selection of the auditor and the audit team. Also, the form of presenting the conclusions should be well planned. (Kuusisto, 2000, p. 152)

In a case study, Kuusisto (2000) showed how an auditor's health and safety expertise is important to evaluating a company's compliance with legal requirements. The reliability of the audit tool was also highly important. Kuusisto assessed reliability from both the perspective of intra-observer reliability (an assessment of how consistently the studied behaviour or phenomenon is observed by one person in different times) and from the view of inter-observer reliability (an estimate of how consistently the studied behaviour or phenomenon is observed by two or more persons independently at the same time). The study compared companies in the USA and Finland. The results revealed that the organisation and administration of safety activities was at a higher level in the companies in USA than in the companies in Finland. There were no differences in the level of industrial hazard control, control of fire hazards and industrial hygiene. Accident investigations and analyses were significantly better organised by companies in the USA. The biggest differences between companies could be seen in supervision, participation, motivation and training activities. (Kuusisto, 2000)

Both safety measurements and auditing can be harmful if they are poorly or wrongly focused. Levä (2003) notes that safety audits focus on occupational health and safety from the perspective of the BS 8800 and OHSAS 18001 standards. They do not, therefore, necessarily serve the prevention of major accidents within the company. It was assumed that internal audits did not focus on major accidents. (Levä, 2003, p. 116–117) A structured safety audit method can be reliable, but is less valid if the wrong questions are asked (Kuusisto, 2000, p. 152). Validity is a measure of how accurately a method or scale describes the actual situation. Validity is often divided into content validity, criterion validity, and construct validity. (Downie and Heath, 1970 in Kuusisto, 2000)

When arranging an audit, the nature and extent of the audit should be determined. For example, it is important to decide whether the audit will examine the whole or just part of an organisation, or focus on a specific activity, location or issue. (BS 8800 1996) The study examined for this thesis involved participation in part of three organisations' internal process safety audits. The audits in question focused solely on process safety rather than the entire safety management system. Within safety critical organisations in particular, it is important to ensure that audits cover all aspects of the safety management system. Bearing this in mind, it is good practice to divide audits by activity, location or the issue being examined.

2.5.2 Inspections

Safety inspections are not the same as safety audits. Inspections can be defined as monitoring conducted within an organisation in order to locate and report existing and potential hazards that might lead to accidents in the workplace. Inspections are often thought of as being conducted by authorities. They occur at line or operating level and reveal the potential causes of accidents, providing an opportunity to take corrective action before an injury occurs. (The American Chemical Society, 2000)

Safety-related inspections within organisations can be performed by occupational health and safety authorities, environmental protection authorities, fire authorities and the authorities in charge of surveillance related to the Seveso Directive. Due, in part, to differences in legislation, authorities have their own inspection methods and systems. Inspections can be related e.g. to certain permits, or can be periodical inspections. In addition, they are sometimes related to projects undertaken by the authorities or to accidents that have occurred: i.e. they can involve inspections of certain fields of industry or processes.

Both the comparative study and the section on the development of scoring systems deal with inspections by Tukes. The comparative study was partly conducted alongside periodical Seveso inspections and the inspection scoring system was applied to comparing the visited establishments. The scoring system applied in inspections is developed in the development section of this thesis. Inspections of Seveso establishments are being introduced in chapter 2.9.2.

2.6 Process safety indicators

Performance indicators can be used in all areas of a business e.g. sales, finance, human resources and occupational health and safety. Nowadays, there is also an interest in using performance indicators to measure process safety. Measurements of safety are very important in Seveso establishments as it is in other safety critical organisations. A range of tools are available for auditing safety. In safety management systems, audit tools often focus on personal safety. In addition to these, there is a need for process safety indicators for controlling risks. Safety indicators are tools used for ensuring an effective safety management process.

Safety performance measurements can be structured as a four-fold system, whose effectiveness can be assured using three positive inputs by safety management (Figure 2.10):

- plant and equipment which reduces the risks posed by identified hazards as far as is reasonably practical
- systems and procedures for operating and maintaining equipment and managing activities
- competent personnel for the operation of plant and equipment and the implementation of systems and procedures

With the help of these three inputs, negative outputs or failures can be prevented. Safety performance measurement must cover all four of these areas. (van Steen, 1996) Management systems and procedures are assessed during inspections and through Tukes' scoring system, which is also applied and further developed in this study.

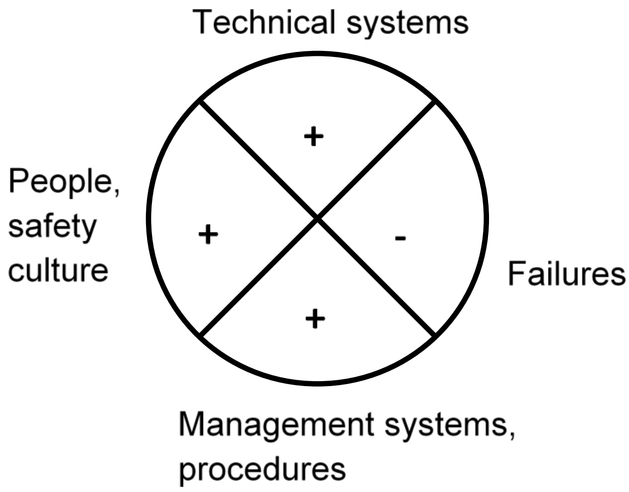

Figure 2.10: Safety performance measurement (van Steen, 1996; Henttonen, 2000; Lehtinen and Wahlström, 2002)

There have been many discussions and articles on safety indicators over the last decade. A range of approaches and views are on offer. (HSE, 2006; Dyreborg, 2009; Erikson, 2009; Hopkins, 2009; Baldauf, 2010; CCPS, 2011a; Reiman and Pietikäinen, 2012; American Petroleum Institute, 2013; Laitinen et al., 2013)

One approach to categorisation would involve applying two dimensions of safety performance indicators: personal safety versus process safety indicators, and lagging versus leading indicators (Table 2.5). This would entail the possibility of lagging and leading indicators in both personal and process safety. (Hopkins, 2009) The OHSAS 18001 standard and some studies (e.g. Laitinen et al. 2013) refer to proactive and reactive measures of performance. When applied in this context, ‘proactive’ has the same meaning as ‘leading indicator’ and ‘reactive’ has the same meaning as ‘lagging indicator’. Organisations often apply safety performance indicators such as injury data or days of absence after an injury etc. However, if an organisation is interested in how well it is managing process safety risks, it must develop specific indicators of process safety performance.

Table 2.5: The 2-dimensional indicator space (Hopkins, 2009)

	Lead	*Lag*
Personal		
Process		

According to this theory, *lagging indicators* are the most common indicators. Such indicators measure the outcomes of activities or events that have already happened. Lagging indicators show when a desired safety outcome has failed, or has not been achieved. (HSE, 2006) Examples of lagging indicators include spills from primary containment, spills affecting the environment or gaseous emissions into the air. However, it is difficult to identify effective lagging indicators that are applicable to process safety, mainly because major process safety incidents do not occur frequently enough to develop into a statistically significant trend. There are also difficulties in recognising process safety events for example a leaking pump seal can be fixed without knowing how close a major accident was to occurring. (American Petroleum Institute, n.d.)

Leading indicators provide information for use in anticipating and developing organisational performance (Reiman and Pietikäinen, 2012). Leading performance indicators therefore focus on input and describe how to achieve the main objective in question and how to improve, while lagging performance indicators focus on output and describe how well a management system is performing. (Erikson, 2009; Dyreborg, 2009) Leading indicators can be e.g. the number of field visits and inspections, the number of safety audits and the number of safety communications and safety meetings (American Petroleum Institute, n.d.).

The HSE guide advises organisations to set both leading and lagging indicators for each critical risk control system within a process safety management system. Together, these confirm that a risk control system is operating as intended or that it provide a warning of developing problems. (HSE, 2006) Figure 2.11 reveals how leading and lagging indicators are present in each risk control system. Lagging indicators reveal the holes in control systems (malfunctions, near misses, incidents and accidents), while leading indicators identify failings through routine checking.

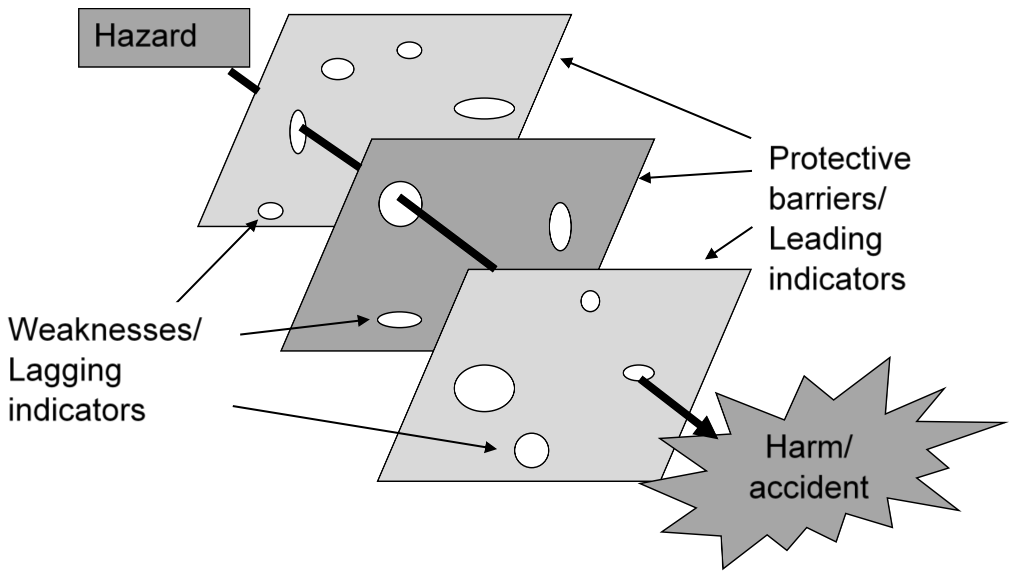

Figure 2.11: Leading and lagging indicators in an accident model (HSE, 2006; CCPS, 2011a)

There is another way to describe process safety indicators. In Figure 2.12, the safety pyramid is divided into four tiers:

- Tier 1 depicts process safety incidents. The events involved are e.g. actual losses of containment of greater consequence. This tier has most lagging indicators.
- Tier 2 depicts process safety events. The events include e.g. loss of primary containment events of lesser consequence, but may be predictive of more significant incidents.
- Tier 3 depicts near misses. Such events are challenges to safety systems and could have led to an incident. Indicators provide the opportunity to identify and correct weaknesses within the safety system.
- Tier 4 depicts unsafe behaviour or insufficient operating discipline. Such indicators represent the operating discipline and management system performance. This tier contains most leading indicators. (CCPS, 2011a; American Petroleum Institute, n.d.)

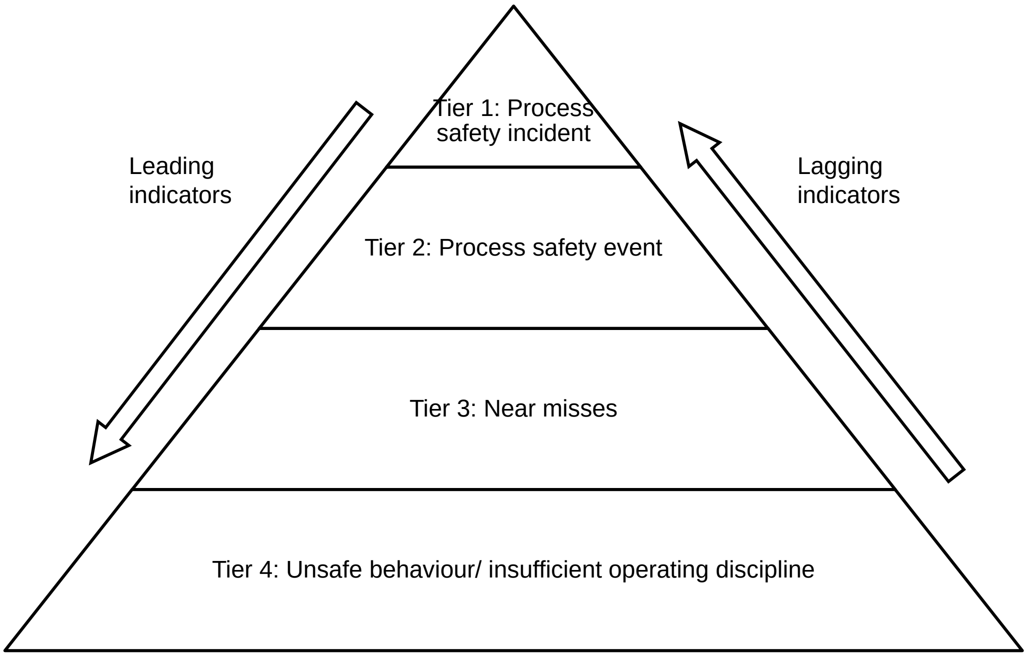

Figure 2.12: Process safety indicator pyramid (CCPS 2011a; American Petroleum Institute 2013).

There is a range of opinions on whether the distribution of lagging and leading indicators is relevant. Hopkins (2009) writes that the distribution of lagging and leading indicators is not a relevant issue when setting performance indicators: the main issue is to choose indicators that measure the effectiveness of the controls upon which the risk control system relies. Hopkins (2009) describes how the same indicator can be classified as a lagging indicator or a leading indicator, depending on the perspective adopted. It is therefore not essential to focus on defining the type of indicator rather than providing indicators which anticipate and develop safety performance. In addition, Mearns (2009) claims that we should consider no longer dividing indicators between leading and lagging indicators, but focus on key performance indicators of safety instead. Within a company, key performance indicators are chosen based on a range of aspects and must be quantifiable and tied to specific targets (Baldauf, 2010).

On the other hand, Dyreborg (2009) writes that it would be important to develop reliable models of the causal relationship between leading performance indicators and lagging performance indicators. Erikson (2009) also disagrees with some of Hopkins' ideas. He stresses that there is a fundamental difference between leading and lagging indicators and that is why both are needed.

Reiman and Pietikäinen (2012) divide indicators into three instead of two types: drive indicators, monitor indicators and outcome indicators. *Drive indicators* measure the fulfilment of the selected safety management activities. They form the basis of the control measures used to manage a system. Drive indicators consist of e.g. the number of management walk rounds per month, the contractors trained on safety culture issues and the work practices of the client organisation, and whether or not the organisation has analysed potential accident scenarios and taken preventative measures. *Monitor indicators* describe the potential and capacity of the organisation to perform in a safe manner. They also monitor changing conditions outside the organisation. Monitoring indicators can measure issues such as the extent to which personnel report that their work is meaningful and important, the quantity of slack resources required to cope with unexpected or demanding situations and the percentage of safety-critical equipment that fails during inspections or tests. *Outcome indicators* measure the results of a process or activity. They can provide information on the functioning and failure of safety barriers. Outcome indicators are e.g. the number of reported near misses, loss of primary containment and the availability of safety systems.

Laitinen et al. (2013) studied the validity of an occupational health and safety indicator. They believe that the lack of effective proactive indicators may be the greatest current problem in occupational safety and health management. The most commonly used indicators are reactive – effective proactive indicators are needed. While such statements apply to occupational health and safety, the situation is the same for process safety indicators.

Lähde (2005) introduces the Tukes safety indicator project, which involved the authority's indicators applying to electrical equipment, pressure equipment and the industrial handling of chemicals. The purpose of such indicators is to monitor changes in safety levels as a function of time in determining the safety status of the aforementioned sectors and the relevant changes within it. The main idea is that the safety level cannot be adequately determined by monitoring the number of accidents only. Predictive indicators are required in addition, to show that the absence of any impediment or damage is due to systematic action aimed at preventing accidents. As part of this study Lonka et al. (2004) analysed how technical safety is being monitored by the responsible authorities in Norway, Sweden, the Netherlands, the United Kingdom and Canada. A general trend was revealed whereby the focus is moving from collecting data on incidents to monitoring industry practices (the implementation of various safety practices, measures and management systems). The new approach is thought to provide a better indication of the current overall safety level and how it is likely to develop. All of the studied countries collect data on accidents, which is used by the authorities to target their work. In spite of this, such monitoring cannot be thought of as being based on a specific indicator system.

A company's performance has traditionally been evaluated mainly on the basis of financial performance. However, in terms of safety the measurement of financial performance does not provide effective guidance on whether or not people are doing the right things in the right way. One of the basic problems involved in measuring safety performance is that many important indicators are qualitative, while many of the quantitative indicators are less important. Because quantitative indicators are easier to measure, less important issues are often measured instead of key ones. The point of using indicators is to gain early signals of changes in safety performance and thereby to predict and prevent undesirable incidents. (Lehtinen and Wahlström, 2002, p. 2–3) No indicators can be identified which would fit operations and establishments of every kind – indicators must be set while bearing in mind the related goals and the ways in which the organisation is trying to achieve them.

According to the classifications described above, Tukes' scoring method includes both the leading and lagging indicators observed, but mainly emphasises leading indicators. From the input–output perspective, the indicators mainly comprise input indicators.

2.7 Legislation and standards

2.7.1 Legislation

Major accidents have occurred during the history of the chemical process industry. Following the Seveso accident in Italy in 1976, measures began to be taken to prevent and manage such accidents. The first Seveso Directive (82/501/EEC) was adopted in 1982, and was superseded by the Seveso II Directive (96/82/EY) in 1996. The Seveso II Directive was extended by Directive 2003/105/EC and then superseded by the Seveso III Directive (2012/18/EU), which entered into force in June 2015. References to the Seveso Directive in this study concern the Seveso II Directive. On the other hand, it should be borne in mind that the differences between the Seveso II and Seveso III Directives are irrelevant to this study (European Commission, 2011).

The main reason for renewing the Seveso Directive is the changed labelling system for dangerous chemicals, due to the adoption of the Globally Harmonised System (GHS) and the Classification, Labelling and Packaging of substances and mixtures (CLP). Few changes in scope seem to be in prospect, although some sites may change from upper tier to lower tier sites or vice versa. More changes are expected in terms of public information, public participation in decision making and access to judicial remedies in environmental matters. The level and quality of information available to the public needs to be improved and such information should be, actively provided and made available electronically. The inspection system, on the other hand, will remain based on the risk profile of the sites in question. In the future, notifications from operators must include information about establishments and other sites located nearby. (HSE, 2013) According to the impact assessment performed under the Seveso III Directive, these changes will have no effect on the costs caused by the Directive. (European Commission, 2010) It has also been tentatively suggested that the number of establishments on which requirements will be set in accordance with the Seveso III Directive will not change significantly from the number of those affected in a similar manner by the Seveso II Directive. The Seveso Directive currently applies to thousands of establishments with dangerous substances. (Hallintovaliokunta, 2011 and European Commission, 2011)

The Seveso Directive is intended to prevent major accidents involving dangerous substances. Another aim is to limit the consequences of such accidents for both people and the environment. The Directive includes topics such as safety management systems, emergency plans (both internal and external), land-use planning, briefing and consultation of the public, accident reporting and inspections. (European Commission, 2011)

Within the European Union, the Seveso Directive states what should be done in order to prevent major accidents. It also obliges companies to provide information on the risks posed by their operations to the local population, but does not define how this should be achieved. Each country has developed its own regulations defining the practical implementation of the Seveso Directive, which has resulted in different requirements for chemical plants in different member states. Co-operation between the competent authorities is crucial to the Directive's implementation. The frequency of major accidents fell by some 20% between 2000 and 2008, which suggests that the Seveso Directive is meeting its objectives. The fact that the Seveso approach has been copied worldwide is further evidence of its success. (European Commission, 2010, p.3)

In line with the Seveso Directive, regulations aimed at preventing accident hazards were transposed into Finnish chemicals legislation by The Act on the Safety of the Handling of Dangerous Chemicals and Explosives (390/2005), The Decree on the Surveillance of the Handling and Storage of Dangerous Chemicals (685/2015) and The Decree on the Safety Requirements of Industrial Handling and Storage of Dangerous Chemicals (856/2012). In addition, special legislation has been passed on LPG (liquefied petroleum gas), natural gas and explosives: The LPG Decree (858/2012), the Explosives Decree (473/1993, amendment 524/2013) and The Natural Gas Decree (551/2009).

The Seveso Directive has received both praise and criticism. Pey et al. (2009) used practical examples to demonstrate the differences between Member States in terms of:

- the methods used to identify major accident scenarios,
- the criteria used to define identified scenarios,
- the thresholds used to evaluate the consequences of various scenarios,
- the risk acceptance criteria used to determine whether an industrial activity generates a tolerable/ acceptable/ unacceptable risk for the population and the surrounding environment.

In their paper Pey et al. point out that the Seveso Directive has failed to create or even impose a uniform methodology for the assessment of major hazards. The various methods applied differ in terms of their complexity and quality, the time required to generate results and the costs. It is also crucial to realise that rather small amounts of substances can pose a hazard. (Pey et al., 2009) In their article, Vierendeels et al. (2011) reviewed the change process occurring since the Seveso Directive. Continuous changing and updating of the related legislation has taken up a great deal of European and local governments' resources. In the case of legislation aimed at preventing major accidents adaptations are mainly steered by, and depend on the impetus provided by, accidents that actually occur. In addition, private companies must analyse and implement new legislation, a process which can often be very difficult and expensive. Companies need a highly effective preventive policy if they wish to forestall the implementation of new legislation. According to the literature and interviews underlying the study, preventive policies come in two forms: a source-based policy grounded on the best available risk assessment techniques, or an impact-based policy grounded on land-use planning. (Vierendeels et al., 2011)

2.7.2 Standards

Safety management is handled in line with a range of obligatory standards in addition to legislation. ISO 9001 concerns quality management and ISO 14001 environmental management. OHSAS 18001, on the other hand, concerns occupational health and safety management (based on the British standards BS 8800). These all have a similar structure and OHSAS 18001 was prepared in order to be compatible with ISO 9001 and ISO 14001 enabling the inclusion of all the standards in the same operating and management system. The first version of OHSAS 18001 dates back to 2000 and was renewed in 2007. (Laitinen & Vuorinen & Simola, 2013, p. 182) Table 2.6 shows a comparison between the content of the Seveso II Directive and the OHSAS 18001 standard. The ISO 31000 standard concerns risk management and is therefore connected to safety. In most cases, compliance with standards does not guarantee the fulfilment of legislative obligations.

Table 2.6: The safety requirements of the Seveso II Directive and OHSAS 18001 standard. (OHSAS 18001, 2007 and Directive 96/82/EY, 1996)

Seveso II Directive	**OHSAS 18001**
Prevent major accidents and limit their consequences for people and the environment	Continuous improvement of OH&S management system
Major accident prevention policy/ safety report, safety management system	OH&S policy
Description of dangerous substances, risk analysis and prevention methods	Hazard identification, risk assessment and determination of controls
Has entered into force within national legislation, requirement can vary in different countries	Legal and other requirements are followed
Action to control conditions or events and limit their consequences	Resources, roles, responsibility, accountability and authority
Arrangements for training staff	Competence, training and awareness of personnel
Public information on safety measures	Communication (internal, contractors, external), participation of workers and consultation with contractors
Management of change	Management of change
Planning for emergencies	Emergency preparedness and response
Notification of an accident	Incident investigation
Inspections by the authority, audit and review of the safety management system	Audit, management review

2.8 Authorities

The Seveso Directive demands that Member States appoint a competent authority responsible for the Directive. The related responsibilities can be assigned to the authorities operating at either national or regional level. While this can be more than a single authority, steps must be taken to ensure that the duties in question are fully coordinated. Bodies can also be established to assist the authority at technical level. The responsibilities of such bodies cover issues such as inspections, land use planning, safety reports, external emergency plans and actions following major accidents. (Directive 2012/18/EU, 2012)

2.8.1 Authorities in Finland

In Finland, Tukes is the competent authority driving compliance with the Seveso Directive. Tukes maintains and promotes the nationwide technical safety culture in order to protect people, property and the environment. It also grants licenses to establishments which handle and store dangerous chemicals and performs inspections of such establishments. It also examines safety reports and handles notifications of accidents, investigates larger scale accidents and maintains a register of accidents. The purpose of supervision of industrial handling and the storage of dangerous chemicals is to prevent explosions, fires, releases of chemicals, operational errors, equipment failures or accidents of any other kind, and to limit their effects and consequences.

Municipal rescue services also have responsibilities under the Seveso Directive, drawing up external emergency plans based on companies' internal emergency plans. Rescue services also engage in drills together with each Seveso establishment at least once every three years. These are based on both the establishment's internal emergency plan and external emergency plan, and are run in cooperation with all establishments in the area. In addition, the rescue services perform fire inspections of Seveso establishments – once a year in most cases.

Seveso establishments are usually obliged to apply for an environmental permit from the environmental authorities. This requirement is based on the Environmental Protection Act (86/2000) which enacts the European Union Directive on Integrated Pollution Prevention and Control (IPPC). In Finland environmental permits are issued by Regional State Administrative Agencies (AVI) and the outturn of such permits is monitored by the Centre for Economic Development, Transport and the Environment (ELY). In some cases, the authority in charge of permits and surveillance can be the municipal environmental authority. (Valtion ympäristöhallinto, 2011)

Finnish labour and occupational safety legislation is monitored by the country's occupational health and safety administration, which also investigates serious accidents in the work place. The occupational health and safety administration ensures that the company has listed and evaluated the risks associated with the chemicals used and stored within an establishment, and that chemicals are used in a safe way and labelled as required. (Työsuojeluhallinto, 2012)

When Tukes plans the inspection of an establishment, it invites the rescue services, environmental authorities and occupational health and safety administration to participate in the inspection. They can also perform their own inspections of the establishment (on the basis of legislation other than the Seveso Directive). When a new Seveso establishment applies for a permit from Tukes, Tukes always requests a statement from the municipal rescue services, environmental authorities (Centre for Economic Development, Transport and the Environment) and the Occupational health and safety administration.

2.8.2 Authorities in other countries

A study of small process plants in Europe showed that the authorities play an important role and are considered crucial source of information. The companies were mainly satisfied with their compliance with the regulations, but stated that it is impossible to be aware of all of the regulations and changes within them. They also mentioned the need for greater attention to the problems experienced by small and medium sized companies with respect to health, safety and environmental issues. (Harms-Ringdahl et al., 2000)

The authorities and their surveillance responsibilities under the Seveso Directive differ greatly between EU countries. In some countries, a single competent authority may be responsible for monitoring all safety, environmental and occupational health and safety issues. In most countries, more than one competent authority is responsible for surveillance intended to ensure the implementation of the Seveso Directive. The procedures introduced by different countries in this respect are mainly based on discussions of visits and co-operation between the EU’s Seveso authorities. Such countries may also have other practices, which are not mentioned here.

In Belgium, establishments have been divided into three categories. The frequency of inspections ranges from one to three years, depending on the category of establishment. Belgium has an inspection group of inspectors from the regional environmental authority – the Chemical Department of the Ministry of Labour and Ministry of Economic Affairs – for each administrative area in the country. At least two inspectors participate in each inspection. A single inspection takes several days around four days for each establishment. Prior to the inspection, the establishment receives a series of questions on various themes. The answers are processed during the inspection.

In France, surveillance of the Seveso Directive is realised by Ministry of the Interior, the Ministry of Ecology and Sustainable Development and The National Institute for Industrial Environment and Risks (INERIS) (European Commission 2011). Inspections are carried out every one or two years in France, and there is a guide for inspection procedures. Inspections usually take a day, and are conducted by two inspectors and tend to focus on a few topics, within the Seveso Directive, of which the inspected establishment has been informed in advance.

In Germany, practices differ depending on the state government in question (Bundesland), with responsibilities varying from one federal state to another. One federal state uses a table which helps it to calculate the so-called risk score. The higher the score, the more often the establishment needs to be inspect. According to German law, it is possible to have an external expert, an Inspection Body, perform inspections. In at least some German federal states establishments are inspected every four years by two inspectors at a time.

In the Netherlands, there are three authorities (the rescue services, occupational health and safety authority and environmental protection authority) which conduct inspections together. Inspections of upper tier establishments are held every year and last six days. On three of these six days, the inspection focuses on topics related to the Seveso Directive.

Norway has five authorities monitoring compliance with the decree through which the Seveso Directive is implemented: The Directorate for Civil Protection and Emergency Planning (DSB), The Norwegian Labour Inspection Authority, The Climate and Pollution Agency, The Norwegian Industrial Safety and Security Organization (NSO) and the Petroleum Safety Authority. The authorities form a coordination group which e.g. plans and guides surveillance. Upper tier establishments are inspected every one to three years and lower tier establishments every four years. Check-lists have been drawn up to assist with inspections.

In Sweden surveillance is divided between several authorities: The Swedish Work Environment Authority (AV), The Swedish Environmental Protection Agency (NV) and the Swedish Civil Contingencies Agency (MSB). The AV focuses on occupational health and safety issues, the NV on environmental protection issues and the MSB on fire and explosion hazards. Together, these authorities carry out Seveso inspections. Upper tier establishments are inspected every two years and lower tier establishments every three years, based on checklists created for this purpose.

2.8.3 **Cooperation within the EU**

Monitoring of compliance with the Seveso Directive can differ between Member States, but cooperation between authorities is both necessary and very useful. In addition, a forum exists for representatives of Member States and Commission services, the Committee of Competent Authorities (CCA). The CCA’s tasks are to provide a forum for the exchange of information between Member States and the Commission and to act as a Regulatory Committee when harmonised criteria are being established for derogations. The CCA discusses and issues guidance on all issues concerning the implementation of the Seveso Directive. There is also the Technical Working Group on Inspections, which plans Mutual Joint Visits (MJV). The MJV programme is intended for Seveso inspectors from across EU Member States, who make joint visits in order to learn how Seveso inspections are conducted elsewhere in the European Union. MJVs encourage the sharing and adoption of best practices in inspections. Some Technical Working Groups (TWGs), which prepare guidelines on current topics, have also been established. Such groups are established when needed and consist of representatives of Member States.

The purpose of the European Commission's Joint Research Centre's (JRC) mission is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. The Major Accident Hazards Bureau (MAHB) provides support to the European Community in the formulation, implementation and monitoring of EU policies for the control of major hazards. In this regard, the focus is on the Seveso Directive concerning the processing and storage of hazardous substances. Through guidance, the MAHB tries to assist with the implementation of legislation. Guidance exists for e.g. land-use planning, safety reports, accident reporting and Seveso inspections. MAHB provides the Major Accident Reporting System (eMARS), which is the official reporting software for submitting accident reports to the European Commission in accordance with the Seveso Directive. Detailed and accurate information on past accidents can prove essential to improving safety. (European Commission 2012) The MAHB provides updated information on eMARS for national authorities via the Committee of Competent Authorities (CCA), which meets in support of the active use of the database. (Virallinen lehti, 1999, p. 1-48)

The aforementioned organisations and the structure of cooperation between Member States are given below:

- Organisations of the European Commission
  - Joint Research Centre, JRC
  - The Major Accident Hazards Bureau, MAHB
- Cooperation between competent authorities
  - Committee of Competent Authorities, CCA
  - Seveso Expert Group (also members from countries beyond European Union)
  - Mutual Joint Visits, MJV
  - Technical Working Groups, TWGs (Ahonen, 2015)

2.9 Seveso establishments and the related inspections

2.9.1 Establishments

The Seveso Directive and the related national legislation concern the industrial handling and storage of dangerous substances. Responsibilities for regulatory implementation are determined by the scope of the operational activity in question. Establishment categories are determined by the quantities and classification of the chemicals used or stored. The Seveso Directive refers to two kinds of establishments: upper tier and lower tier. Upper tier establishments are obliged to draw up a safety report and lower tier establishments a major accident prevention policy (MAPP). There are around 130 upper tier establishments and 150 lower tier establishments in Finland (Tukes, 2012c, p. 4).

Upper tier establishments are obliged to draw up a safety report in order to demonstrate that a major-accident prevention policy and safety management system for its implementation have been put into effect (Directive 96/82/EU, Article 9). A safety report is a public document, which demonstrates that major accident hazards and risks have been identified and are being adequately prevented and the potential consequences are being limited, that adequate safety and reliability is incorporated into all aspects of the plant, and that an effective internal emergency plan has been drawn up and implemented. A good safety report provides the authorities with a clear overview of what could happen, how accidents can be prevented and what is being done to ensure, that if an accident occurs, the consequences can be minimised and a clear mitigation plan is in place. Each safety report must also include an updated inventory of the dangerous substances held in the establishment. (Directive 96/82/EU)

Lower tier establishments must establish a major accident prevention policy (MAPP) which designs and guarantees a high level of protection for people and the environment based on the appropriate means, structures and management systems (Directive 96/82/EU, Article 7). The Seveso Directive requires that each operator introduces its major accident prevention policy in a MAPP document and ensures that such a policy be properly implemented. A MAPP document should take account of the principles included in the Seveso II Directive (annex III) in seven areas: organisation and personnel, identification and evaluation of major hazards, operational control, management of change, planning for emergencies, monitoring of performance, and audit and review. (Directive 96/82/EU)

According to the Seveso Directive, the safety management system should cover the part of the general management system which includes an organisational structure, responsibilities, practices, procedures, processes and resources for determining and implementing the major accident prevention policy. The Seveso Directive’s Annex III defines the issues which should be addressed by the safety management system. (Directive 96/82/EU)

2.9.2 Inspections of Seveso establishments

The Seveso III Directive (article 20) requires that the competent authorities have a system of inspections which covers all establishments. The frequency of such inspections can be considered based on a systematic appraisal of the major accident hazards affecting establishments concerned. (Directive 2012/18/EU) The European Commission’s Joint Research Centre (JRC) and Major Accident Hazards Bureau (MAHB) also provide technical support for the competent authorities in the field of inspections (mainly through the Committee of Competent Authorities CCA-cooperation).

According to Finnish legislation, upper tier establishments are inspected once a year, while lower tier establishments are inspected every three years. The competent authority can make exceptions to this based on the results of actual accidents, and depending on safety indicators and the safety management system. The authority must provide the operator with an inspection report in which the main elements are mentioned and inspection and deficiencies can be identified. The Tukes' report also contains scores related to 11 topics on a scale 0–5. While criteria have been developed for giving these scores, they tend to have been based on the experiences of inspectors. When new inspectors start work, they are familiarised with the scoring system through participation in the inspections of experienced inspectors. The system seems to have been designed to take account of differences in score giving between inspectors. Some inspectors can give the same scores as others, but based on less stringent requirements. To keep the criteria uniform, each inspector is supposed to participate in inspections by other inspectors on a regular basis. Due to limited opportunities to do so, this is not always possible to arrange.

Tukes has chosen to use its scoring system in its inspection reports and has been found this to be a good way of obtaining a quick overview of an establishment's safety level. The inspected establishments receive information on how they are managing and can compare the results with previous inspections and other operators. The scores also help the authorities to make the decisions on the frequency of inspections.

The author feels that, while it would be important to maintain the scoring system it needs to be developed. Like auditors, the inspectors should achieve similar results when inspecting the same operation under the same conditions. Limited resources mean that inspectors cannot conduct inspections as a team, which in turn requires that the criteria applied are as objective as possible. Each score also covers a range of single issues, making the score an average based on a more general theme. Bearing this in mind, a new scoring system has been developed in the empirical section of this study.

2.9.3 Scoring system in Finland

Seveso inspection reports in Finland include scores related to seven topics, in accordance with a system based on the Seveso Directive. Inspection scores are given on an 11-level -scale (see Figure 2.13). The scale is from 0 to 5, and half points (0.5) can also be given. Until 2010, quarter scores (0.25 and 0.75) were also in use.

5	**Proactive development**	Encouraged to continue
4	**Good practices**	Positive features identified
3	**Fairly good**	Possibilities for development emphasised
2	**Need for development**	Advised, urged to improve
1	**Significant deficiencies**	Speedy action required
0	**Serious deficiencies**	Immediate action required

Figure 2.13: Rating of activities (scores) and the consequences of them (actions required from the establishment). (Tukes, 2004, p. 5)

As can be seen in Figure 2.13, a score of 5 means that the establishment is demonstrably engaging in the proactive development of its safety work and is being encouraged to continue with its excellent commitment to safety. A score of 4 indicates the implementation of good practices concerning safety, while one of 3 means that the establishment is fulfilling legislative requirements and has the possibility to develop. A score of 2 means that the establishment is in need of development in the sector in question and is advised to improve its safety work. A score of 1 is given when the establishment has major deficiencies and action is required, while a score of 0 means that the establishment has serious deficiencies and action is required immediately.

3 Safety management of nine Seveso establishments in seven European countries

I began planning this study in 2008, when Tukes was interested in comparing process safety levels in Seveso establishments. Most of all, based on the inspections of establishments with good safety practices, Tukes aimed to disseminate information on such practices to Finnish establishments in general, during inspections and other surveillance work. For this study, data on the level of safety and good safety procedures has been collected on the basis of nine establishments through visits, familiarisation with the establishments' documents, and interviews with personnel dealing with safety issues.

The Seveso Directive requires Seveso establishments to have a safety management system. Within companies, it is common for all such establishments to have the same safety management system in use, which is often certified by an accredited company. In this study, all of the participant companies were using a common safety management system in all of the visited establishments. A common safety management system simplifies comparisons between sites within a single company, while making such comparisons more useful by affording the possibility of exploring whether there are different ways of executing the same management system.

3.1 Materials and methods

The study was carried out in co-operation with three companies (A, B, C) and their Seveso establishments in seven different European countries:

- Company A's establishments were located in
  - Finland (<200 employees, both continuous and batch processes)
  - the Netherlands (>100 employees, both continuous and batch processes) and
  - Germany (>50 employees, both continuous and batch processes).
- Company B's establishments were located in
  - Finland (<10 employees, highly automated process, which was operated mainly from another establishment)
  - Sweden and (< 10 employees, highly automated process, which was operated mainly from another establishment)
  - Norway (> 100 employees, highly automated process).
- Company C's establishments were located in
  - Finland (>100 employees, batch processes)
  - Belgium (approx. 100 employees, batch processes) and
  - France (>100 employees, batch processes).

The Seveso Directive applies to all EU countries. Norway is not a member of the EU but it has implemented the Seveso Directive in an almost identical manner to Member States.

This study focuses on Seveso establishments which are obliged to draw up either safety reports or major accident protection policies. The companies which participated in this study volunteered to do so. After deciding to conduct the study, Tukes asked two companies to participate. One refused, but the other (company A) consented. While visits to company A's establishments were underway in 2009, yet another firm, company B, was invited to join the study. Company B's visits were held in in 2009–2010. Company C volunteered to join the study after hearing that one company was still needed, and company C's visits were held in 2010–2011.

All of the participating companies were known to put a great deal of effort into safety work in their establishments in Finland. Based on inspections of the companies' Finnish establishments by Tukes, it was also known that the companies had good safety practices in place. The companies themselves chose the establishments to be visited for the purposes of this study. With regard to the Finnish Seveso establishments included, the visits coincided with the periodical Seveso inspection. In company A, all visits coincided with the company's internal process safety audits, which is why the visits to company A took longer (three days in most cases) than those to companies B and C (one to two days).

All of the visits were conducted in 2009–2011. They were conducted in English, except for the visits in Finland, which were in Finnish. The agenda (Appendix A: Agenda of the visits undertaken for the study) was sent to the establishments in advance. It helped the personnel of the establishments to prepare for the visit and the questions we intended to ask. In addition, before the visits a meeting was held with the Finnish contact person of the company. The establishments were asked to deliver some advance information on the establishment, which helped with the planning of and preparation for the visits. Each visit was conducted based on a group of 3–4 persons, mainly inspectors from Tukes, in addition to one or two contact persons from the visited company. The auditors in this project were all familiar with process safety surveillance and the assessment methods used. Auditors in the visits are shown in Table 3.1.

Table 3.1: Auditors in the visits (from Tukes).

	Company A			**Company B**			**Company C**		
	FIN	NL	GER	FIN	SWE	NOR	FIN	BG	FR
Person 1 (the author)	x	x	x	x	x	x	x	x	x
Person 2	x	x	x						
Person 3	x	x	x						
Person 4				x	x	x	x	x	x
Person 5				x	x	x			
Person 6				x	x	x			
Person 7							x	x	x
Person 8							x	x	x

As can be seen from Table 3.1, the same group visited all three establishments of one of the companies using the same auditors made the comparison work easier. On the other hand, a different group visited each company. The author (person 1) was present at all nine visits. Each group was formed so that at least one expert on the company's processes and techniques would be present; such a person had been performing inspections and other surveillance of the same branch of the process industry for many years. In each, case group had at least two members with more than 20 years of experience of inspecting competent authority. The educational background of members is mainly technical; eight have a university degree (seven in technology and one in chemistry) and one has a degree in engineering.

The agenda for each visit included time allocated to each of the following:

- **The establishment and its operations:** Basic information on the site's operations, products, raw materials, neighbours, main risks etc.
- **Recognition of the requirements of legislation**: How well the company has recognised official and safety requirements. Also, how legislative changes are handled.
- **Management and personnel's commitment:** Management and personnel commitment to safety and management's procedures to maintain, assess and improve company's level of safety.
- **Risk assessment and management of change:** How the company has recognised and assessed dangers and risks. How safety aspects are considered in decision making.
- **Identification of safety requirements (technical requirements, operating instructions, competence and training):** How well the company has defined the requirements it needs to take into consideration e.g. when planning new operations, lay-outs, process equipment, maintenance, guidance and training.
- **Emergency preparedness:** The coverage of procedures during accidents, incidents, deviations, process failures or claims.
- **Site visit:** A tour of the process and storage area chosen beforehand.

A more detailed agenda for the visits is given in Appendix A: Agenda of the visits undertaken for the study.

The comparison was based on the discussions held during the visits, the documents received from establishments (safety report, risk assessments, internal emergency plan and safety key figures) and observations made during site tours.

All visitors from Tukes were experienced in using the assessment scale (the scores) during inspections. A written memo was drawn up of each visit, alongside the visiting group. The memo included the scores for each of the aforementioned topics on a scale of 0–5 (Figure 2.13) given together with the auditing group. Although the group did not reach a consensus on the scores in every case, a solution was found based on discussions. The assessment criteria are shown in Appendix B: Current criteria for scores given during Seveso inspections in Finland. In addition, observations of good practices were made by the personnel of the establishments and the competent and local authorities.

For this study, comparative work was performed based on a study involving a visit to nine Seveso establishments from three different companies. As a research method, case studies are suitable for a range of empirical studies. However, there are also problems associated with case studies: controlled observations of the kind associated with laboratory work are difficult; a case study cannot be repeated and the results are often impossible to generalise. (Järvinen and Järvinen, 2004, p. 61 – 62) Case studies can be either single-case or multiple case studies, and data is gathered using questionnaires, interviews, observations and document reviews. Data can be both qualitative and quantitative. A case study tries to explain long-term causality and processes and answers questions of ‘how’ and ‘why’. (Järvinen and Järvinen, 2004, p. 78 – 81)

A qualitative study focuses on the real world and real situations on a holistic basis. A researcher cannot observe the associated findings with complete objectivity because his or her values configure the ways in which the studied phenomena are understood. (Hirsjärvi et al., 2000, p. 161) In qualitative studies, the objects of study tend to be selected on a fully articulated rather than a random basis. Research plans are typically formed as the study progresses. (Hirsjärvi et al. 2000, p. 164)

Some theories uphold that case studies only serve to strengthen the researcher’s preconceptions, while others make the opposite point; the results have the potential to be less biased than a theory based on conclusions, which are, in turn, based only on theories. Weaknesses are also involved in using case studies as a research method. Researchers working with large amounts of data can lose sight of the key relationships involved in the case in question. Case studies can also result a theory, which is not amenable to broader application. Close connection between case studies and empirical reality improves the validity of the results and their reflection to reality. (Kuusisto, 2000, p. 76)

In type, this study is a comparative and benchmarking case study. It involves the collection of qualitative data based on observations, discussions, study documents received from the establishment and the analysis of reports written based on visits. Visitors familiarised themselves with the establishments beforehand by reading the company's website and presentation material, if these had been obtained. The visits were mainly hosted by the plant managers and the people responsible for process safety in the site area. During the visits, data was collected based on interviews with safety managers and plant managers. Visitors were introduced to documents such as risk assessments, safety reports, internal emergency plans, training programmes, ATEX-documents (atmosphères explosibles), plans and outturn of maintenance. Visitors also made observations on a site tour, which, in most cases, included a tour of some parts of the site. It was not possible to survey the entire site area, or inspect all of the establishment’s operations, during such a short visit.

For this study, the quantitative data comprises the scores accorded to establishments. After the visit, a report was written together with the visiting group. The visitors also gave scores to the establishments on seven topics introduced earlier. For this scoring, the same scale was used as in the Seveso inspections in Finland – a scale with 11 levels (see Figure 2.13).

In the results, establishments are compared with each other's within and between the participant companies. In addition, official procedures are compared with the procedures followed in Finland. Because the companies whose establishments were visited were using the company's safety management system, it was assumed that the establishments were using similar practices and procedures. In addition, interesting observations could be made on how much the safety management system affects the establishments' procedures and how they can differ with regard to the principles and rules applied.

The study included visits to three establishments from each of the three companies in different countries, including Finland. The establishments in each company have the same kinds of processes and procedures and are technically similar. They also use the same management system. The processes underlying this study are shown in Figure 3.1.

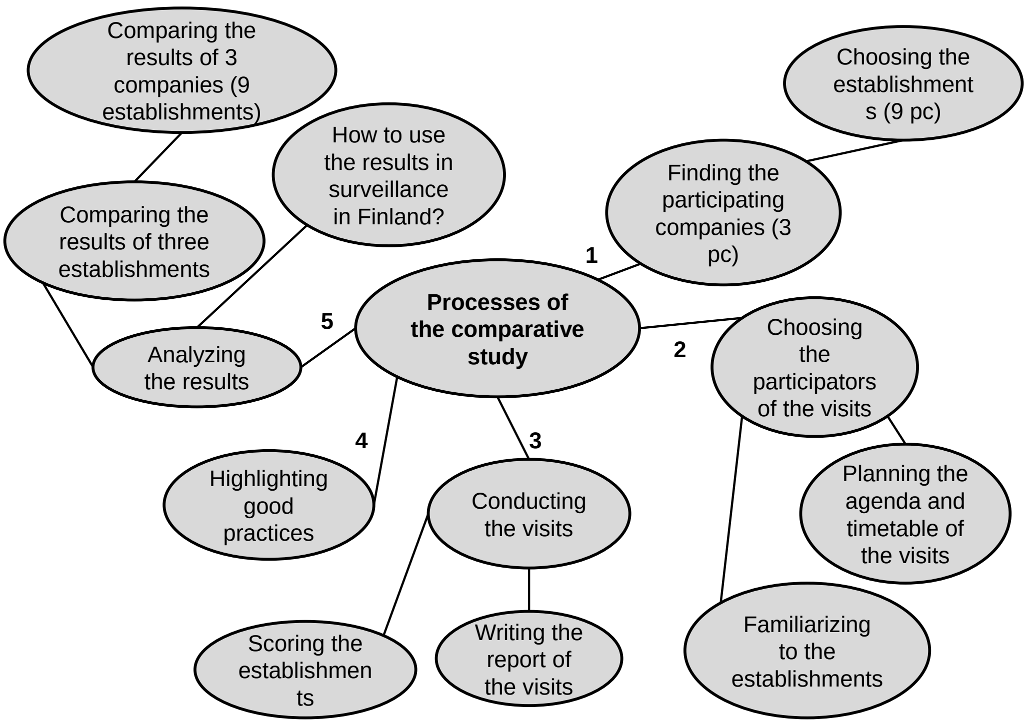

Figure 3.1: The processes and phases of the comparative study

As can be seen in Figure 3.1, the companies participating in this study were chosen at the beginning of the project, while the actual establishments to be visited were chosen in cooperation with the companies. Individual membersof the inspection groups were chosen once the kind of establishment in question had been identified; sufficient knowledge and experience of the field of industry in question were considered crucial. The visits were planned in advance, in cooperation with the participating group, and the establishments sent the group information and material on their operations. The schedules for each visit had to be planned carefully due to the fact that, in most cases, only one day could be spent on the site area. During each visit, the members of the group made their own notes. Afterwards, these were discussed, observations were made and the report was written up. The group also gave the establishment scores immediately after the visit, to ensure that their recollection of the institution's performance was as good as possible. The good practices observed in each establishment were highlighted straight after each visit. After the completion of all three visits to each company, the results were analysed together with the auditing group. The three establishments were compared to each other and, after all the company visits had been made, to all of the other eight establishments. Finally, a more general discussion was held in Tukes on how to use the results to enhance plant surveillance and the safety of Seveso establishments in Finland.

In most cases, the scores were given alongside the visiting group after the visit. The group determined the score, which was often a compromise between varying opinions, in the wake of the discussions. For company C's establishment in France (the last visit), scores were given on a different basis due to difficulties in arranging a meeting which all members of the visiting group could attend. Each auditor gave a score of his or her own, after which the group discussed and decided on the overall score. Even in cases where the scores varied, the total score was close to the average of the auditors' individual scores. All scores given to establishment in France of the company C are shown in Table 3.2, which reveals differences in relation to a few of the topics. In three topics out of seven, all of the establishments were given the same score: recognition of the demands of legislation, management and personnel's commitment and competence and training. In relation to risk assessment and management of change 0.5 higher. In relation to three of the topics, the level of variation was higher, at 1.0: technical requirements and the condition of equipment, operating instructions and emergency preparedness.

Table 3.2: Scores given by each auditor to company C's establishment in France.

The assessments of the company C's establishment in France					
	Auditor 1	**Auditor 2**	**Auditor 3**	**Auditor 4**	**Final score**
Recognition of the demands of legislation	4	4	4	4	**4**
Management and personnel commitment	3.5	3.5	3.5	3.5	**3.5**
Risk assessment and management of change	3.5	3.5	3.5	4	**3.5**
Technical requirements and condition of the equipment	3.5	3.5	3	2.5	**3**
Operating instructions	4	3.5	3	3.5	**3.5**
Competence and training	3.5	3.5	3.5	3.5	**3.5**
Emergency preparedness	4	3.5	3	3	**3.5**

3.2 Results

In this chapter, the results of the comparison of safety procedures and safety levels are introduced. With reference to safety procedures, the focus was on both positive actions and observations of issues in need of improvement. The differences between the actions taken by the competent authorities were also highlighted. The positive safety procedures observed were often small issues and improvements were based on common standards. Because they were also potentially useful in other establishments, we have listed them below. The establishments were also evaluated using scoring system applied to inspections conducted in Finland. Scores were given on the basis of seven topics.

No serious or significant deficiencies were observed in any of the establishments. Based on the very fact that the companies in question had been chosen as good examples, it was assumed that the establishments visited had established good safety practices. In addition, the establishments were chosen as a benchmark of good practices. No great variation was evident in the scores given for the various topics or to the establishments. On the other hand, comparisons between the establishments revealed that many procedures were divergent.

3.2.1 Observations on safety procedures

During the visits, the group made observations based on both documentations and discussions and actual operational situations. Differences in procedures, techniques and practical procedures were observed during the visits. The positive observations made are given in the list below. In most cases, the visits lasted 1–2 days but in Company A they lasted 3. These longer visits, created more time to make observations, particularly during site visits. Most observations recorded in the table are therefore of Company A's establishments.

Co-operation with neighbouring companies varied. This naturally depended on how close the area's establishments were to each other. Process safety indicators (e.g. leaks, near misses, ratio of proactive and reactive actions during maintenance, ignitions) were applied variably. In some establishments, safety indicators were mainly applied to occupational health and safety matters (sick-leave, accidents etc.). The scope and accuracy of risk assessments varied. Various kinds of official requirements often lay in the background. Labelling of chemical tanks varied, as did co-operation with municipal rescue services.

In terms of recognition of legislative requirements, comparisons were difficult due to the fact that the authorities in each country have varying demands and practices e.g. on reporting to authorities. All establishments received information on changes in legislation and the actions required in their own company, or from an outsourced service. Legislative changes tend to be viewed as demanding work because the establishments must follow so many laws and decrees and legislation is continuously changing. In Germany, the establishment was part of a large industrial park, where the industrial park's service company followed changes in legislation and informed establishments of these when necessary. This was considered good practice. Outside Finland, none of the establishments were required to name a person in charge of handling dangerous chemicals.

The management and personnel commitment was implemented differently in different establishments, despite the uniform guidance given to companies. The establishment in the Netherlands had a good and proactive way of self-assessing its safety culture. Use of process safety indicators was highly variable and indicators have traditionally been related to occupational health and safety, e.g. days of sick-leave and accidents. In the Netherlands, the establishment had invested in process safety indicators, which were observed at the level of teams, departments and the whole establishment. Such indicators included safety observations, near misses, leaks, human error and the ratio between proactive and reactive actions. In Norway, the commitment to safety was apparent in daily tasks, such as instructions for use, within the visited establishment.

Risk assessment and management of change was handled to a different extent and accuracy within the various establishments. A major reason for this was the varying demands set by the authorities. In the Netherlands, the authorities required accurate calculations of the adequacy of rescue procedures, based on risk assessments. In Germany, risk assessments were mainly performed with respect to operational changes and the method used was HAZOP (Hazard and Operatively Analysis, a qualitative technique carried out by a team and widely used for identifying hazards at the process design or operational stage.). Most but not all of the establishments had assessed the consequences of the various scenarios and calculations of the physical effects of accidents. Taking account of guidance on organizational (in Germany) and temporary (in Finland) changes was considered good practice in managements of change. Reaction matrices and consequence analysis were performed with varying coverage and accuracy. It was unclear how the demands of the authorities affected the results e.g. within the Swedish establishment, the authority played a greater role in risk assessments than in Finland. The authority had taken part in risk assessment when in other countries it had often set requirements and accepted the final risk assessments produced (while not taking part in the assessment work itself). Access control was closely monitored, particularly in company C's establishments. Company C had software which its establishments used to document e.g. incidents, accidents and near misses, but not all of its establishments were able to view the documentation of other establishments. Such documents would constitute good risk assessment tools and drill topics.

Good technical practices were observed in terms of the marking and visibility of fire water piping and emergency showers (in the Netherlands). In addition, loading and unloading areas were well lit in the Netherlands and the establishments had invested in developing a serviceable locking system during maintenance work. The maintenance of safety critical equipment was more frequent than that of other equipment. Within the operators' working area in Germany, attention had been paid to the labelling of pipelines and valves. Company A was using the same risk management software in all of its establishments, but in a different way and some more and some less intensively.

Good examples of operating instructions were observed in Germany, where the instructions were brief but very clear. One A4 sheet had been drawn up, listing the key safety fact about each chemical. Many of the establishments had the rule that loading and unloading had to be done by the establishment's own personnel, not the truck driver. Some also locked the valves, so that the driver could not load or unload the vehicle. The work permit system was generally well organised and covered dangerous work fairly well. In company B, one establishment used more operators to perform the same operations than the other two, for reasons that remain unclear. In France, the operating instructions were highly detailed, but they were no observed in action during the visit.

Supplementary training was organised in the Netherlands at both individual and team level. In Finland, attention had been paid to the training of foreign truck drivers. An interpreter was used when needed.

Industrial parks often have their own rescue services, which may specialise in accidents that are typical when dangerous chemicals are involved. Municipal rescue services do not have the opportunity to develop such specialisations. The industrial parks also tended to engage in close co-operation in managing accidents and compiling internal emergency plans (Germany and Sweden). There was some variation in training related to accidents and incidents and undertaken together with the rescue service.

In this study, I focus on the positive findings, while presenting some observations on issues in need of development, more of which are shown in the list below. A fairly common deficiency was lack of use of process safety indicators. While safety indicators have been improved, they often focus on occupational health and safety. The use of the company's risk management software varied greatly and could be usefully applied to improving the handling of near misses. During change planning, safety issues are handled in accordance with an agreed procedure and temporary changes are often not considered to be changes, even when they would have a far greater impact on safety than some permanent changes. Chemical storage tanks should always have a bund, which is fairly easy to arrange. However, tanks without bunds or other arrangements for handling leaks were observed. When creating a safe working environment, the labelling of equipment and communication of information (e.g. on the content and direction of the flow of pipes, EX-zone or EX-equipment) for people working in the establishment can be crucial.

The observations made during visits to establishments were as follows:

- **Recognition of the requirements of legislation**:
  - \+ Accident scenarios are clearly described in the safety report and they are used for emergency planning (NL)
  - \+ Effective and versatile monitoring of regulations (GER)
  - − Challenges must follow changes in legislation if the company lacks an external service for this (NL)
- **Management and personnel commitment:**
  - \+ Risk management software used effectively for e.g. auditing deviations and safety walks (FIN)
  - \+ Discussions with the neighboring companies are an effective means of addressing problems (GER)
  - \+ Splitting up of safety targets: the entire plant, departments and teams (NL)
  - \+ All incidents registered and taken seriously (NL)
  - \+ Versatile and plentiful safety indicators e.g. operator errors (even those that did not lead to an incident) and a 60% target ratio between preventive and corrective maintenance (NL)
  - \+ A strong commitment to safety work (NOR)
  - \+ Good and precise safety informing for people visiting the site (SWE)
  - \+ Safety manager holds a yearly safety talk with all employers (BEL)
  - \+ Systematic documentation (FRA)

- – Lack of indicators for describing process safety in particular (FIN, GER, SWE)
- – Reporting to the company’s risk management software varies and is sometimes very minimal (GER)
- – Near misses are not always handled properly (FIN)
- – The use of protective gears is not demanded of visitors (BEL, FRA)

- **Risk assessment and management of change:**
  - + Risk assessment of underground pipelines (FIN)
  - + Safety level assessed using the SIL (Safety Integrity Level) method (NL)
  - + Comprehensive and systematic management of change (FIN)
  - + Management of change divided into three categories, including with respect to organizational changes (GER)
  - + Good definitions in relation to management of change (NOR)
  - + HAZOP performed carefully and comprehensively (GER)
  - + Comprehensive accident scenarios (NL, SWE)
  - + Good access control in the site area (FIN, FRA)
  - – Lack of reaction matrices for chemicals (GER, NOR)
  - – In risk assessment no worst case scenarios and or the related consequences (GER)
  - – Management of change did not always include temporary changes (GER)
  - – During risk assessment, it would sometimes be useful to think ‘outside the box’ (GER)
  - – Access to the site area and to process areas is not sufficiently well coordinated (FRA)
- **Technical requirements:**
  - + Fire-fighting water collected into underground reservoirs without drains (FIN)
  - + Good lighting in loading bays (NL)
  - + Plenty of crash barriers (NL)
  - + Systematic way of handling equipment in ATEX areas e.g. stickers on inspected pieces of equipment (NL)
  - + Good lock-out system for maintenance work (NL)
  - + Emergency showers clearly indicated with big green light (NL)
  - + Safety critical equipment listed, criticality has an influence on inspection frequency (NL)
  - + Marking of zones which require protective gear (NL)
  - + Good labelling on some pipelines, including origin and destination (GER)
  - + Three-step waste water checking before allowing drainage into a river (GER)
  - + Emptied and cleaned containers well labelled and in their own designated areas (GER)

+ Good definitions of equipment requirements (SWE)
+ Centralised purchase of equipment and services within the company (FIN)
+ Concentration on prevention maintenance (NOR)
+ Inspections of electrical equipment required more often by permit than legislation (BEL)
+ Easy to observe the condition of cable trays (FRA)
− Unneeded objects often kept in places where they do not belong (BEL, FIN, FRA)
− Labelling sometimes done in different ways within the same establishment (can be confusing) (NL)
− Emergency showers do not start automatically when someone steps into them, are connected to cold water (GER)
− Chemical storage tanks are not always equipped with bunds (GER)
− Places without labelling (pipelines, EX-zones etc.) (BEL, FRA, GER, SWE)
− Forklift without a warning sound or light when reversing (GER)
− Only one valve in pipes where samples were taken (BEL)
− Fire doors kept open (should always be closed) (BEL)

- **Operating instructions:**
  + Good pre start up safety review (NL)
  + Loading and unloading in co-operation with the operator, only the operator can open the filling valve (GER, NL)
  + Chemical sample taken before unloading (NL)
  + Clear instructions for emergency situations (GER)
  + Good information exchange during shift changes, half-hour overlap (GER)
  + Instructions read, understood and signed (GER)
  + Instructions for changes in safety automation e.g. locking (NL)
  + Clear and concise operating instructions (FIN, SWE)
  + Outsourced contractors registered in the control room (GER)
  + Good and comprehensive work permit system (FIN, GER, NL)
  − Work permits not kept in the control room (operators cannot see them) (GER)
  − Information for foreign drivers not in their own language (NL)
  − Protection gears not always used when needed/ required (BEL)

- **Competence and training:**
  + Qualifications and competences listed in job descriptions (FIN)
  + All staff have a 2-hour safety information training session on a biannual basis. Learning is tested with an exam. (FIN)
  + Interpreter present during training sessions for foreign drivers (FIN)
  + Year-long induction for new operators (NL)

- + Further training planned at team and individual level and followed up (NL)
- + Team leaders have their own training programme (NL)
- + A great deal of training and refresher courses (GER)
- + Comprehensive safety training for outsourced workers too (BEL)
- – Refresher training on general safety issues only, not on pressure vessels, electrical equipment or for transport advisors (FIN)
- – No test at the end of training (BEL)

- **Emergency preparedness:**
  - + Risk management software is used effectively (FIN, NOR)
  - + Internal emergency drills 4 times a year (FIN)
  - + Corrective actions registered in risk management software (FIN)
  - + 2 emergency drills per year together with the rescue services (NL)
  - + Own fire brigade (GER, SWE)
  - + Industrial park's own consultant company (expert on the area) (GER)
  - + Emergency preparedness well planned, based on good instructions (GER)
  - + Co-operation with other industrial sites in the same area (not industrial park) (SWE)
  - + Good information sheets for rescue services at the site (NOR)
  - – Training on internal emergency plan (drills) is too seldom (FIN)
  - – Personnel not properly briefed on internal emergency plan (FIN)
  - – No fire extinguishers near storages (FRA)

3.2.2 Scores given to the establishments

All of the establishments were given scores on a scale of 0–5 in a similar manner to that applied in the periodical inspections performed by Tukes. These scores were given for seven different topics and the related assessment criteria are shown in Appendix B: Current criteria for scores given during Seveso inspections in Finland. In Table 3.3, Table 3.4 and Table 3.5 below shows the scores of all three companies and their establishments. The scores given are based on the issues handled in relation to each topic and vary between 2 and 4.5.

It can be seen from Table 3.3 that, among company A's establishments, the one in the Netherlands had the highest scores in all categories except recognition of the requirements of legislation. Each establishment was given a score of 3 in one topic and a score ranging from 3.5–4.25 in the others. When comparing the average scores on company A's establishments, it can be seen that the Netherlands has the highest score and Finland the lowest. When the average scores for each topic are examined, the table shows that company A has the best procedures in terms of operating instructions. The lowest scores were given for three topics: recognition of the demands of legislation, management and personnel's commitment and emergency preparedness.

Table 3.3: The scores of all visited establishments in company A.

Company A	**FIN**	**NL**	**GER**	**Average**
Recognition of the demands of legislation	3.5	3	4.25	3.6
Management and personnel’s commitment	3.5	4.25	3	3.6
Risk assessment and management of change	3.5	4.5	3.5	3.8
Technical requirements and condition of the equipment	3.5	4	3.5	3.7
Operating instructions	3.5	4.25	4	3.9
Competence and training	3.5	4.25	3.5	3.8
Emergency preparedness	3	4.25	3.5	3.6
Average	3.4	4.1	3.6	3.7

It can be seen in Table 3.4,that in company B, the scores varied less between establishments than in company A. When the average scores of company B’s establishments are compared, it can be seen that Norway has the highest score and Finland the lowest. The average scores for each topic indicate that company B has the best procedures in ‘terms of management and personnel’s commitment and ‘competence and training’. The lowest scores were given in ‘recognition of the demands of legislation’.

Table 3.4: The scores of all visited establishments in company B.

Company B	**FIN**	**SWE**	**NOR**	**Average**
Recognition of the demands of legislation	3	3	3.5	3.2
Management and personnel's commitment	3.5	3.5	4	3.7
Risk assessment and management of change	3	3.25	3.5	3.3
Technical requirements and condition of equipment	3.5	3.5	3.25	3.4
Operating instructions	3.5	3.5	3.5	3.5
Competence and training	3.5	3.5	4	3.7
Emergency preparedness	2	3.5	4.5	3.3
Average	3.1	3.4	3.8	3.4

In Table 3.5 it can be seen that there was also very little variation between establishments in company C. The establishment located in Finland was given slightly higher scores on a few topics than those in Belgium or France. When the average scores of company C's establishments are compared, Finland has the highest score and Belgium the lowest. When examining the average scores for each topic, it seems that company C has the best procedures for the recognition of the demands of legislation. The lowest scores were given for technical requirements and the condition of equipment.

Table 3.5: The scores of all visited establishments in company C.

Company C	FIN	BEL	FRA	Average
Recognition of the demands of legislation	4	3.5	4	3.8
Management and personnel’s commitment	3.5	3.5	3.5	3.5
Risk assessment and management of change	4	3.5	3.5	3.7
Technical requirements and condition of equipment	3.5	3	3	3.2
Operating instructions	4	3.5	3.5	3.7
Competence and training	3.5	3.5	3.5	3.5
Emergency preparedness	4	3.5	3.5	3.7
Average	3.8	3.4	3.5	3.6

The total average scores given to establishments vary little: Company A's establishments are given average scores of 3.4–4.1, Company B's establishments are given average scores of 3.1–3.8 and Company C's establishments are given under average scores of 3.4–3.8. The average scores given under each topic are shown in Table 3.6.

Table 3.6: The average scores of all establishments by topics.

Averages for all topics	
Topic	Average
Recognition of the demands of legislation	3,53
Management and personnel’s commitment	3,58
Risk assessment and management of change	3,58
Technical requirements and condition of equipment	3,42
Operating instructions	3,69

Competence and training	3,64
Emergency preparedness	3,53

In Figure 3.2, the scores listed in the above tables are shown in a way which allows the scores for establishments in Finland to be compared to those given for establishments in other countries. The scores are averages of those shown in the tables above. It seems that the only clear difference in favour of the establishments of others lies in the topic of emergency preparedness. Other topics show only a small difference and for most the Finnish establishments have slightly lower scores than their foreign counterparts. The Finnish establishments were given higher scores than others only for technical requirements and condition of equipment. No significant, statistical differences could be observed between the scores for Finland and those for other countries (two sample two-tailed t-test, separate variance, 95% confidence interval -0.057–0.402, t=-1.525, df=37.5, p=0.136). The reasons for this may be the lack of actual differences between establishments in Finland and those in the visited countries. We should bear in mind that the material used for this study is too limited in scope to allow us to generalise on the results achieved in all establishments. In addition, the method used can be too insensitive for indicating differences between these issues.

Figure 3.2: Averages of the scores given to all establishments. Finland includes three establishments (one from each company) and the others include six (NL, GER, SWE, NOR, BEL, FRA).

For three of the seven topics, the deviation between the scores given was low:

- In the area of technical requirements and condition of equipment, all of the scores are between 3 and 4.
- In the area of operating instructions, all of the scores are between 3.5 and 4.25.
- For competence and training, all scores are between 3.5 and 4.25.

One topic has a significantly higher deviation than the others:

- For emergency preparedness the scores are between 2 and 4.5. There is also a great deal of variation between the establishments in each of the companies.

3.2.3 Actions of the authorities

Because the observations below are based on one establishment visit per country, it is highly probably that the authorities engage in different practices and procedures to those mentioned. For example, in Germany procedures differ depending on the federal state government in question (Bundesland).

Monitoring of compliance with the Seveso Directive is handled in various ways between member states. In some countries (e.g. Sweden), the Seveso authority is also responsible for environmental protection or rescue services. In addition, co-operation between the authorities varies. In some countries, inspections are conducted together with a range of authorities. In Finland, separate inspections are performed under the Seveso Directive with respect to environmental protection and fire safety. In some countries, inspections are varied out under themes which vary each year. Upper tier establishments are inspected once a year in Finland. If an establishment has been given high scores and has achieved good results in safety work, inspections can be less frequent – every two or three years. The Finnish establishments we visited for this study were all inspected every two years.

The duration of inspections varies. In Finland, each inspection lasts one day. In the Netherlands, three authorities conduct joint inspections lasting six days while three others focus on topics related to the Seveso Directive. In Germany, the establishment holds an inspection every fourth year, involving two inspectors. Under new arrangements in Norway, a questionnaire can be answered in place of undergoing an inspection.

There were also differences between permits. In Finland, a new permit is required as a supplement to permits previously granted, before engaging in major operational changes. There is therefore a wide range of possible permits related to the operations of an establishment. In the Netherlands, a single permit can be altered if operations change. In every case, just one permit covers all of the establishment’s operations. While most of the permits were restricted to topics concerning to Seveso Directive, some included regulations on environmental protection. In Norway, a new procedure allowed establishments to notify the authorities of their operations, which were registered without any need to grant a permit as such.

In most cases, safety reports concern only one establishment, but in Germany a single, mutual safety report covered many of the upper tier establishments in the industrial park. In France, the establishments must report to the authority every year on the realisation of the safety goals listed in the safety report, and must report on a great many issues.

Differences between the practices of various authorities were observed in relation to some technical requirements and other individual topics. Legislation and official requirements differed with respect to issues such as the frequency of inspections of pressure vessels, chemical tanks and electrical equipment. Some establishments were delighted with the guidance provided by authorities. In some fields of operation in particular (e.g. manufacturing or handling of explosives), they can be very precise.

Some observations on the actions of the authorities are introduced below:

- Conduct inspections in co-operation with other authorities
- Inspections have themes on which the inspection is focused
- Also requirements related to annual reporting to the authorities (on the realization of the goals set in the safety report)
- Safety reports can also be conducted jointly with other establishments
- The authority’s conclusions on the safety report are not issued in every case (despite the fact that the Seveso Directive requires this)
- No requirement exists for persons designated as being in charge of chemical safety (except in Finland)
- Variation in how precise and comprehensive risk assessments must be
- Differences in handling permits during changes in processes (in some places, a new permit is also required in the case of minor changes, while in others change can be handled during inspections)
- Bunds are not required for chemical tanks in every case
- Differences in frequencies of inspections of electrical equipment, pressure vessels, chemical tanks and safety valves
- Requirements on video surveillance of loading areas
- Requirements on analysators for chemicals in loading areas
- The role of inspection bodies varies with regard to technical inspections (in some countries, inspections by some authorities can be performed by an Inspection Body)
- Differences in the amount of guidance provided to establishments

- For some branches, more detailed guidance is provided than for others
- Some require that a one-page safety information sheet on each chemical be presented in the control room
- Close co-operation between the establishment and the municipal rescue services

4 Development of the scoring system

The current scoring system of Seveso inspectors in Finland has been in use since 2005, and it has many positive aspects:

- The inspectors give scores to the establishments in relation to certain topics. The scoring system enables the authority to assess the risks posed within establishments on a numerical basis, and to compare establishments with each other.
- These scores help authorities to evaluate where they should focus their resources during monitoring, by identifying whether certain topics or fields of activity seem to require more of the authority's attention.
- The operators of the establishments have given positive feedback on the current system. The scores provide them with information on the level of process safety within their establishment. They can also see the development in process safety in establishments between inspections.
- As in the mentioned theoretical framework, the root cause of an accident can be defined as the combination of conditions and factors underlying accidents or incidents (Hollnagel 2004 p. 51). One of the ambitions behind the scoring system used in inspections is to identify the possible root causes that could lead into an accident in the future.

Despite the advantages of the current system, there are areas in need of improvements:

- The current scoring system can be subjective and is challenging to learn for a new inspector.
- The assessment and scores given can vary depending on the inspector. In the case study, one establishment was given scores individually by the team members, which showed that differences exist even between the more experienced inspectors (Table 3.2).
- In addition, several factors can affect the score for a single topic in question and probably does not, therefore, serve to identify the good procedures or weaknesses concerned.

Positive experiences of the current system suggest that there is no need to abandon or radically change the scoring system. However, this study includes the development of a new scoring system for Seveso inspections in Finland, based on experiences of the current one. In this study, the term ‘current scoring system’ refers to the system in use during the comparative study. Since then, some changes have already been made to the topics related to the inspection and have been taken into account as part of development work. For example, the management of change has been separated out to form its own topic.

There are currently 11 scoring scales, of which only half tend to be used; the lowest scores are given only when operators have been highly neglectful of safety and the highest scores are ‘reserved’ for exceptionally high safety performance. The scores are introduced in paragraph 3.2.2 and in Table 3.3 – Table 3.5. Figure 4.1 shows the scores given by inspectors in Finland in 2013. From there, it is clear that no scores 0 or 5 were given and scores of 0.5; 1; 1.5 and 4.5 were seldom given. Scores of 2 and 4 were given in fewer than 10% of cases. Scores of 2.5 and 3.5 were used in 15–20 % cases. A score of 3 was the most used score, being given in 40% of all cases. Scores of 2.5–3.5 (three out of eleven possible scores) were used in 77% of all cases. The figure indicates that the scores follow a standard distribution.

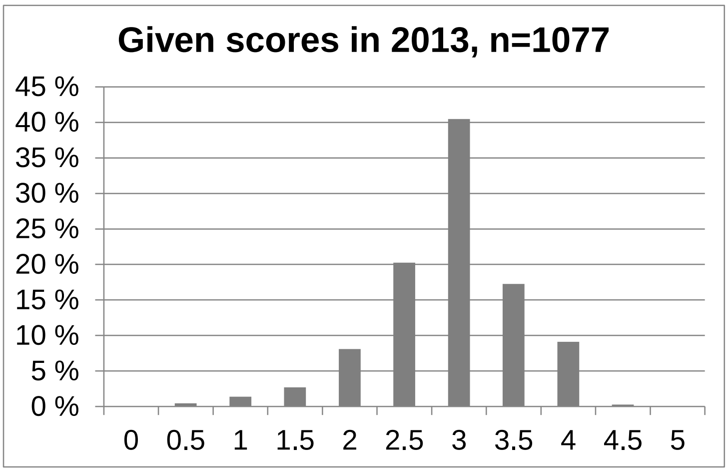

Figure 4.1: Scores given by inspectors in 2013. These include establishments other than Seveso ones. (Tukes, 2014c)

4.1 Materials and methods

The current scoring system applied to Seveso establishments in Finland has been divided into seven categories. All of these categories include several smaller components that the inspector have to consider when giving the score:

- **Recognition of the demands of legislation**
  This part of the inspection clarifies how well the establishment has recognised the legislative and official requirements. The follow-up of legislation and changes in regulations and standards are also assessed. This part also involves assessing how well the requirements of chemical and explosives licences and the safety report/ MAPP-document have been met.

- **Management and personnel commitment**
  This category involves evaluating the commitment of management and personnel to safety matters. The methods and tools used for assessing safety (safety targets, safety policy, management systems etc.) and the way in which the management shows its commitment to safety matters are also discussed and assessed.

- **Risk assessment and management of change**
  In this section, the identification of the associated dangers and systematic risk evaluation are assessed. In addition, the decision-making process and how account is taken of safety issues within such a process are evaluated. Hazards due to changes and how the related responsibilities are handled are also evaluated. Risk assessment and management of change have been divided into their own categories.

- **Technical requirements and condition of the equipment**
  Here, the requirements placed on technical solutions and operational conditions are specified and documented (maintenance, automation, equipment, machinery, lockout-tagout, inspections etc.).

- **Operating instructions, competence and training**
  Working instructions, the work permit system and training of personnel are assessed in this category, as are staff competencies.

- **Emergency preparedness**
  Planning and preparing for emergencies are evaluated under this heading. Legislative requirements under this perspective include issues such as internal emergency planning and training by the rescue services. Cooperation with other establishments nearby is also assessed.

- **Site tour**

> Observations are made during the site tour and interviews within personnel e.g. in the control room. These observations provide information on how the principles are regarded in practice.

Development of a new scoring system began by the author with the creation of a new list of detailed questions on topics related to the current system. The questions can be viewed in the test form in Appendix C: Form used for testing the new scoring method. The processes involved in such development work are shown in Figure 4.2. More detailed questions are set under each topic within this new development system, enabling the provision of an average score for the topics currently being applied. Some adjustments have also been made to the topics. The most problematic issue with regard to the current system concerns the scope of the scale; the score given to an establishment is a subjective issue. For example, a score of 3.5 can mean that, for the topic in question, the establishment meets all of the set requirements fairly well, but it may also indicate deficiencies in some areas and excellent performances in others. This is due to the fact that the topic covers several elements and the score is an average one for these.

For this study, new method was developed by the author in cooperation with Finnish Seveso inspectors. Based on the author's own experience as an inspector and discussions with some of the inspectors, the author formed a list of detailed questions on the topics of the current system. When the first version of the list was finished, a two-hour workshop was held involving most of Tukes' inspectors. Various issues were discussed in the workshop and feedback on them was given. Afterwards, the author made some changes based on the feedback, finalising the list of questions for test use.

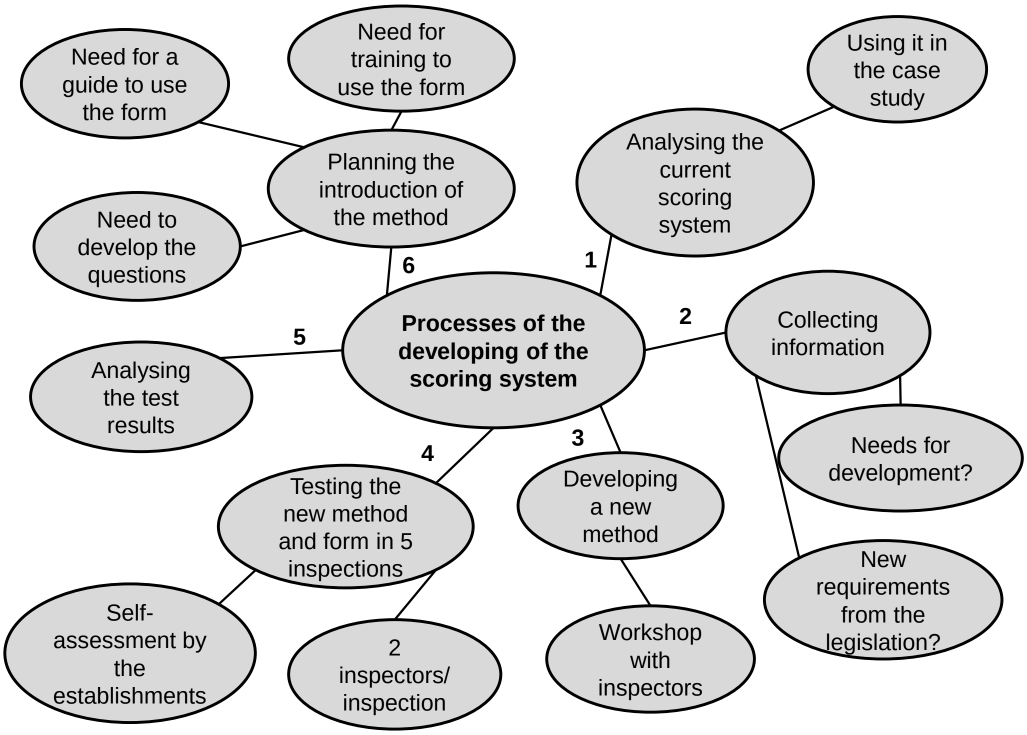

Figure 4.2: Processes and phases in the development of the scoring method.

The method was tested by conducting inspections in pairs and comparing the independently given scores between inspectors. The inspectors chose these inspections themselves, based on their inspection agenda during the testing period. The establishments in question are therefore not representative of all Seveso establishments in Finland. The form used for testing the new scoring criteria can be seen in Appendix C: Form used for testing the new scoring method. A total of 67 questions are listed, divided under the seven topics introduced earlier.

There are different types of detailed questions; ones which are quite easy to answer based on the data, such as “safety report provided on time” and there are ones that need more assessing and skills, such as “content of safety report”. The idea is that not all questions have to be filled in by the inspector on each inspection.

4.1.1 **Materials**

When the new scoring system was ready for testing, the inspectors and establishments involved were chosen. Three pairs of experienced inspectors were chosen to participate in the test. This was done jointly by the author and the inspectors’ manager, based on the discussions held in the workshop and the work load of the inspectors. The five establishments were chosen based on the timetable of the participating inspectors: each inspector chose one establishment for the test. Although the plan was to test the system through six inspections, one of the planned inspections could not be done. The tests were conducted in establishments due for inspection during the testing period of 2013–2014. In most cases, whereas one of the inspectors was familiar with the establishments, the other was visiting for the first time. This may have affected the scores, since the more experienced inspector was in possession of more latent information than the first-time visitor, who was forced to base the score solely on the current visit.

The scores given during the test are not as comparable as in the comparative part of the study and the establishments visited then. The companies and establishments involved in the study were known to achieve good results in terms of process safety performance, but the establishments selected for testing the system were chosen based on the inspection schedule.

4.1.2 Assessments by inspectors

The scale for the new system will be renewed to create a four-step scale (0, 1, 2 and 3), which includes the option of leaving a question unanswered if it is not applicable to the establishment or the subject in question is not handled during the inspection. The scale is as follows:

- 0: does not fulfil the requirements
- 1: partly fulfils the requirements
- 2: fulfils the requirements
- 3: exceeds the requirements
- not applicable

The testing was performed by three pairs of experienced inspectors, based on five test inspections in total. The aim was that they would perform each assessment independently in order to reveal the differences between the assessors. Unfortunately, only three of the inspections were conducted in this way, while two were assessed based on cooperation between the two inspectors. The 67 questions on the form were divided into eight topics. Five of the inspections of the establishments also involved a self-assessment based on the same form.

The new system can be expected to provide more information, both to the authority and the operator of the establishment in question. Its more detailed questions and the related scores will help readers to discern, from the inspection report, where the process safety strengths and weaknesses of establishments lie. Whereas the current system is based on seven scores, as mentioned above the new system has 67. It can be assumed that the new system will provide more reliable assessments of the procedures and level of process safety within the establishment, while bringing additional sensitivity to scoring. When giving scores, an inspector must bear legislative requirements in mind. If changes in legislation are expected, this will not necessarily entail adjusting the questions, but the scores will have to reflect the new requirements.

The number of steps in the scale will fall markedly; the current 11 steps will be replaced by four. This should to reduce the element of subjectivity and therefore the differences between inspectors. The new scale has a clearer relationship with the current legislation and the level of its requirements.

The list developed for such inspections includes a set of questions dedicated to the site tour. The test results for the test the site tour were handled in the same way as for any other topics, being given its own average. In the related discussion, it is recommended that account be taken of the scores for the site tour based on the averages of the topics which the question concerns in each case. This will prevent an average score being created for the site tour itself.

4.1.3 Self-assessments

The method is also intended for use as a self-assessment tool; the form can be delivered to the operator prior to the inspection and the person responsible for process safety can give his or her answers to the questions. The questions and operator's answers can then be discussed during the inspection and the inspector can either agree with the operator or give another score in each case.

4.2 Results

The results of testing the new scoring system can be divided into two parts: although the given scores can be explored, it was thought more interesting for the purposes of his study to examine the differences between the inspectors exhibited when giving scores to establishments. When using this kind of form regardless of the inspector giving the scores the results should be as similar as possible. Of course, this requires that the inspectors are qualified and experienced in their work.

4.2.1 Given scores

When examining the averages of the given scores (Table 4.1) it can be seen that the average for all of them was 1.61 on a scale of 0–3. There was some variation between the average scores for the inspections, but not great deal. The lowest average for inspections was 1.37 and the highest 1.80. The topic given the lowest scores was management of change (1.38), while the site tour was given the highest (1.82). In this case, the site tour was given its own scores and average. Because these results were gathered for only a few inspections, no conclusions can be drawn concerning other establishments. When the scoring method is more widely used, the average score for all of the establishments can help the authority to identify areas where improvements will be required in the future. It can also constitute feedback on the topics in relation to which e.g. more guidance or even changes in the regulations and legislation are required. For example, low scores in the management of change could be improved with the help of actions by the authority (newsletter, guidance, presentations at process industry events).

The average score provides some information on the safety level achieved by the establishment assessed under each topic, but it is more important that the inspectors can show for which questions they gave scores of 0 or 1. These are the questions in relation to which improvements are needed and which the inspectors should emphasise when giving feedback in the inspection report.

Table 4.1: Averages of the scores for each topic from both inspectors. The scale is 0–3. (0 does not fulfil the requirements, 1 partly fulfils the requirements, 2 fulfils the requirements, 3 exceeds the requirements).

	Inspection 1	**Inspection 2**	**Inspection 3**	**Inspection 4**	**Inspection 5**	**Average of all establishments**
1.Recognition of the demands of legislation	1.50	1.81	2.00	2.00	1.69	1.80
– Range of subtopics	0-2	1-2	2	2	1-2	
2. Process safety management	1.30	1.53	1.64	1.33	1.39	1.44
– Range of subtopics	0-2	1-2	1-3	0-2	0-2	
3. Identification of danger and risk assessment	0.59	1.67	2.00	not assessed	1.50	1.44
– Range of subtopics	0-2	1-2	2		0-2	
4. Management of change	0.75	1.50	1.17	2.00	1.50	1.38
– Range of subtopics	0-1	1-2	1-2	2	1-2	

	Inspec-tion 1	Inspec-tion 2	Inspec-tion 3	Inspec-tion 4	Inspec-tion 5	Average of all estab-lish-ments
5. Technical requirements and condition of equip-ment	1.63	1.62	1.82	1.40	1.40	1.57
– Range of subtopics	1-2	1-2	1-2	1-2	0-2	
6. Operating instructions, competence and training	not assessed	1.93	2.00	1.33	1.85	1.78
– Range of subtopics		1-2	2	1-2	1-2	
7. Emergency prepared-ness	1.78	1.83	2.00	1.92	1.47	1.80
– Range of subtopics	1-2	1-3	2	1-3	0-2	
8. Site tour	2.00	1.64	not assessed	not assessed	1.63	1.82
– Range of subtopics	1-3	1-2			1-2	
Average for all topics	1.37	1.69	1.80	1.66	1.55	1.61

In Appendix D: Test results of the scoring system, average scores are given for each question and topic on the scoring form. Major differences can be seen in the score averages for each question. The overall score average was 1.59. Three questions were given an average score below 1: distribution patterns and analysis of consequences (0.80), Monitoring of and reactions to process safety indicators (0.88) and Setting process safety indicators (0.90). One question received an average score of over 2: Notification based on the safety report for the neighbouring area (2.29). Examining the average scores given for each topic, it can be seen that the highest scores were given for Recognition of the demands of legislation (1.80) and the lowest for Management of change (1.41). The average scores given for each topic indicate the level achieved with respect to the issue in question within the establishments participating in the test; recognition of the demands of legislation is at a fairly high level but action is required with respect to management of change. The results of the tests suggest that similar scores would be recorded for establishments all over Finland. These averages cover several individual questions and their scores, which may vary significantly and that give a much more precise indication than the average score given for the situation in regard to each individual question. This proves that the developed system is more precise than the current system.

4.2.2 Differences between inspectors

Figure 4.3 shows the distribution of the scores between 0–3. From this, it is clear that 2 (meets the requirements) was the most used score during inspections All of the given scores can be seen in Appendix D: Test results of the scoring system. A score of 0 (does not fulfil the requirements) and 3 (exceeds the requirements) were the most seldom-used scores. This suggests that the scale was used in a similar manner to the current 11-step - scale (0–5).

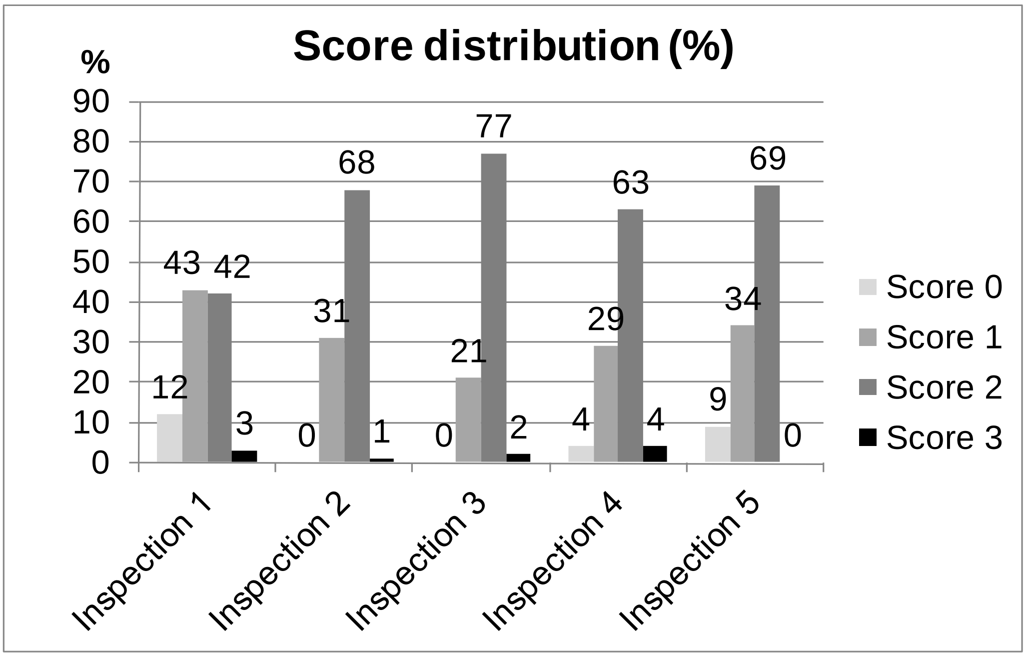

Figure 4.3: Score distribution based on the inspections.

A total of 335 questions (5 x 67 questions) were asked during the testing. Of these, 67% were questions answered by both inspectors and of these 225 questions, in 77% of cases the inspectors gave identical answers and in 22% they had one score disagreement (e.g. one had given a 3 and the other a 2). For 1% of the 225 questions, the scores given diverged by 2, but none diverged by 3. The number of questions under each topic in whose case the results varied ranged from 14 to 42. Inter-auditor agreement rates (identical answers) varied between 63.3% and 87.5%. The number of identical answers to each topic was as follows:

- Recognition of the demands of legislation 80.0% (n=36)
- Process safety management 73.0% (n=42)
- Identification of danger and risk assessment 75.6% (n=25)
- Management of change 63.3% (n=14)
- Technical requirements and condition of equipment 73.6% (n=35)
- Operating instructions, competence and training 85.2% (n=19)
- Emergency preparedness 86.1% (n=34)
- Site tour 87.5% (n=14).

It should be borne in mind that scores were given for two of the inspections (inspections 3 and 4) based on cooperation between the inspectors rather than independently. In the case of these scores, the number of identical answers was clearly higher than in the case of independently given scores.

4.2.3 Self-assessment

The scoring method was tested by the establishments as self-assessment tool. The best way of using the self-assessment form would involve the inspector asking the person responsible for process safety to fill in the form before the inspection and send it to the inspector. During the inspection there would be a chance to discuss scoring and possible differences in opinion between the authority and the establishment being inspected. The inspectors were used to assessing the establishments using the current system, which did not involve self-assessment. This also meant that self-assessment was new to the establishments.

The self-assessments tended to be similar to the scores given by the inspectors. However, in some self-assessments the scores were systematically higher than those given by the inspectors, while in others the reverse was true. As ‘Appendix D: Test results of the scoring system’ shows, in inspections 1 and 5 the self-assessments scores were higher than those given by the inspectors, while in the case of inspection 4 the self-assessment scores were lower. The averages of the scores given by the inspectors and representatives of the establishments are presented in Table 4.2. The self-assessors were in agreement with the inspectors in relation to 33%–82% of the answered questions. The number of questions answered by both the inspectors and self-assessors varied between 24 and 59.

Table 4.2: Averages of all scores given by the inspectors and during self-assessment.

	Inspector 1*	Inspector 2*	Self-assessment	Unanimous between the self-assessment and inspector 1	Unanimous between the self-assessment and inspector 2
Inspection 1	1.26	1.43	1.93	49 %	54 %
Inspection 2	1.67	1.74	1.70	66 %	70 %
Inspection 3	1.77	1.85	1.82	73 %	82 %
Inspection 4	1.68	1.67	1.33	33 %	33 %
Inspection 5	1.47	1.40	1.71	52 %	46 %

* The person is different in different inspections.

The inspectors had previously used the scoring method and were familiar with the development underway, which meant that they were well-versed in the method despite their lack of guidance or training in using the form. For the establishments, the self-assessment part of the tested method was wholly new and they were given no training or guidance in this.

5 Discussion

Compared to issues such as occupational safety, levels of process safety have been difficult to define, and a good level of occupational safety is no guarantee of a high level of process safety. However, the national working culture could support the idea that these safety areas should go hand in hand. A working culture has more effect on occupational safety than on process safety. Occupational safety more concerns attitudes (people tend to be aware of dangerous working practices), whereas process safety concerns understanding processes, and then making decisions based on such an understanding.

The main purposes of this study were to investigate and develop the scoring system used by Tukes to assess process safety and observe good practices in overseas establishments, whether such practices are applied by operators or the authorities. Achieving these aims demanded a great deal of work within the establishments, in the form of inspections and visits. This would not have succeeded without the cooperation of the companies and establishments involved, although the inspectors from Tukes were among the key contributing factors to the success of the project.

The success of the study depended on the willingness of the participating companies to share their knowledge and experiences. The management of the establishments needed to be prepared to participate in open discussions of its actions and procedures, with the aim of identifying good practices in the establishments of the various countries and comparing safety between establishments within and between companies. This aim was realised successfully, with observations being made on a range of practices which could be imported to Finland.

5.1 Validity and reliability

Validity of this study is affected by the used methods and material. A case study is known to be closely connected to reality, and therefore validity of the results of the comparative part can be assessed to be good enough for this study. However, the size of the material in the comparative part (amount of audited establishments) does not give any possibility to say if the establishments in Finland are on a higher or lower level compared to establishments in other countries. In the comparative part both reliability and validity would have been higher if the companies, or at least audited establishments were chosen randomly. This was not even considered when the visits were planned, due to the aim to see especially good practices during the visits. With this perspective, the establishments were chosen in cooperation with the participating companies.

Audit methods need to meet several quality demands. Interrater reliability, sensitivity, content validity and construct validity are the main quality issues (Bigelow P.L. and Robson L.S., 2006).

Content validity means the extent to which the audit questions and criteria are complete according to the particular safety management system requirements. In this study, we can assume that content validity is high enough, because the used audit questions were designed by competent authority. (Bigelow P.L. and Robson L.S., 2006)

Construct validity means the extent to which relationship between audit results and other OHS indicators, like accident rates, are consistent. However, it is very difficult to prove construct validity of any process safety audit method. No reliable data exists on major accidents or process errors that might have led to a major accident. Thus, we need to assume that the content validity also implicates construct validity. (Bigelow P.L. and Robson L.S., 2006)

Sensitivity means the extent to which audit scores can show differences between two workplaces and chances in the safety management in one workplace. Increasing the number of the rated question increases the sensitivity of the audit method. This was also done in the second empirical part of the study. The developed new method can be assumed to be more sensitive than the preliminary one, even if the assessment scale was reduced from 11 to 4 for reliability reasons. (Bigelow P.L. and Robson L.S., 2006)

Interrater (interobserver) reliability means the consistency of audit results when carried out by different auditors or auditor teams. There are many issues having effect on this; comprehensiveness of the audit framework and instructions, competence and independence of the auditors, use of multiple information sources, etc. Interrater reliability can be tested by comparing the scores given independently by different individuals. (Bigelow P.L. and Robson L.S., 2006)

The scores for the audited establishments could have been given in another way; each auditor could have given the scores independently before discussing them with each other. For practical reasons, this interrater reliability test was done in this study only in the last audit and the given scores were consistent enough (Table 3.2). Even in cases where the scores varied, the total score was close to the average of the auditors' individual scores. If all audits were conducted in that way, it would have improved the validity and reliability of the comparative part. Anyhow, that one example indicates that the differences between auditors would have been low also in other audits.

In the development part of this study, several experienced inspectors tested the developed questions. Inter-auditor agreement rates varied between 63.3% and 87.5%. In the author's opinion, this proofs that the reliability and validity of the results are on a good level. The level would have been higher, if both inspectors scored all of the five inspections individually. Now two of the inspections were scored after a discussion of the inspectors, which increased the number of identical answers. Afterwards it is clear, that the author should have highlighted more the meaning of independent scoring to the inspectors before testing the questions. Naturally, a bigger amount of inspections and inspectors testing the questions, would have given more reliable and valid results. However, also in the development part of this study, the validity and reliability can be assessed to be good enough for this purpose.

5.2 Research questions

A range of questions was set at the beginning of this study; the answers to these questions are summarised below based on the results of this study.

<u>How well does the assessment tool work when comparing the level of process safety between establishments?</u>

For this study, the current assessment tool was used in the same manner as in actual inspections of Seveso establishments in Finland. The scoring system is intended to assist in the assessment of process safety procedures gathered under certain topics. It can also be used for comparing establishments with one another. However, the scores should be treated as indicative rather than as a precise measurement of the current situation. Scores can vary by inspector due to the subjectivity of the scoring method, which makes assessments less comparable even if performed by the same inspector. Assessments can also be affected by how well the inspector knows the establishments in question beforehand, or whether he or she is assessing the establishment solely on the basis of the information provided during the inspection. Based on the experiences recorded during this study, it can be said that the assessment system and the related scores are fairly suitable for comparing the level of process safety between establishments.

Little deviation can be observed between the scores, which is understandable since all of the visited establishments have a high level of safety and high scores were expected; the participating companies were known to have invested in process safety and part of the idea was to score their procedures, which had already been recognised as sound.

In addition, the establishments involved were chosen by the companies themselves, making the establishments non-representative when comparing safety between establishments. Only one establishment from each country was visited (except in Finland, where three establishments were inspected), which made the study too narrow for observing and comparing safety levels between countries. The Finnish establishments were mainly selected based on the timetables of forthcoming inspections, leaving few alternatives to choose from. On the other hand, the establishments located abroad were mainly selected on the basis of where the companies wanted to take the group of inspectors. It can be assumed that such establishments were therefore ones with a good reputation for safety within the company concerned. Choosing the establishments randomly might have had an effect on the comparative results given to the establishments.

No significant differences could be observed between the scores for Finland and those for other countries. The reasons for this may be the lack of actual differences, but we should bear in mind that the material used for this study is too limited in scope to allow us to generalise on the results achieved in all establishments. Also the method used can be too insensitive for indicating differences between these issues.

In part, this this study was undertaken in order to compare Finnish establishments with those of other EU countries. With respect to the scores given to companies A and B, the Finnish establishments seem about average or slightly below average. For company C, the Finnish establishment seems about average or slightly higher. The reader should bear in mind that the scores present only one, fairly objective way of ranking the establishments. In this study, much more informative results are provided by the observations made within the establishments.

<u>Are the safety culture and safety procedures similar within each company or do they vary between establishments in various countries? If there are differences, what is the nature of those differences and what are the reasons underlying them?</u>

When analysing the results of the study, should be borne in mind that the observations were made in only one establishment per country. Moreover, only six countries were visited besides Finland. Information was not collected on all EU countries, which means that the results were based on a small, not even random, sample.

A fairly large number of differences were observed between establishments within the same company, even where they had the same safety management system and similar safety principles. The working culture and practices in any given area were long affected by each establishments' historical background. For example, risk assessments were conducted differently, depending on how they had been conducted previously and on the requirements set by the authority in question. While the risk management software could be identical in all departments within the same company, its use could vary markedly. Whereas some establishments felt that the software was a fit with their operations, others (with similar operations) felt otherwise. Software tends to be used more actively if personnel feel that it is useful.

During our visits, we (the inspection teams) made observations on issues affecting the level of process safety in each establishment:

- The commitment to safety of the personnel, particularly management
- The establishments' previous owners: both good and poor practices tend to prevail for a fairly long period after changes of owner
- The age of the establishment and the investments made in it
- Co-operation with other, nearby establishments nearby (historical background, rules of the industrial park etc.)
- National working culture

Authorities also have an effect on the level of safety in establishments, with different authorities demanding different plans and reports. Some countries had more detailed decrees and guidelines, whereas the requirements in others tended to be more based on the establishment's own risk assessments. However, in all companies and establishments having one's own safety indicators was mentioned as an important tool in safety development.

There were major differences between authorities' inspection practices in different countries. The frequency of inspections ranged from one year (in the Netherlands) to four (in Germany) and their duration also varied. In most countries, inspections took only one day, while they took several days in the Netherlands, of which three days concerned the requirements set by the Seveso Directive.

<u>Could good practices in overseas establishments be imported to Finland?</u>

The comparative study focused on positive aspects, such as efficient ways of working safely and good technical and organisational solutions. Observations were made on differences in handling procedures within establishments, but no serious or exceptional deficiencies were identified. Many good practices were observed abroad which could be imported to Finland e.g. certain clauses in permits, guidelines, training or discussions on inspections. Examples of good practices are presented in chapter 3.2.1 (Observations on safety procedures). Due to the simplicity of some good practices, importing them into Finnish establishments would require little effort. However, some practices may require investments or major changes e.g. in lay-out or practices.

We in Finland have much to learn and develop in terms of co-operation between establishments within the same industrial park. In Germany, we saw both positive and negative aspects of such co-operation – some companies felt that the costs outweighed the benefits. Operating in an industrial park requires common rules between all of the companies concerned. The industrial park visited in Germany included a service company which managed the property, buildings and rescue services among other responsibilities. The company was involved whenever the establishments were planning changes. A negative aspect of close cooperation of this kind is that expertise tends to be outsourced and the establishments are focused to rely on the expertise of others.

What are the weaknesses and strengths of the current scoring system?

A detailed list of the strengths and weaknesses of the current scoring system is presented in Chapter 4 (Development of the scoring system). The scores given in the comparative study show only small variation. This was expected due to the fact that the establishments were known to perform well in terms of safety. The average score for the entire establishment in the case of company A varied between 3.4 (Finland) and 4.1 (the Netherlands). For company B, the average varied between 3.1 (Finland) and 3.8 (Norway). For company C, the variation in the average was smallest, between 3.4 (Belgium) and 3.8 (Finland).

The scoring criteria for the current system are not precise and a subjective element, on the part of the inspectors, is always involved. If the criteria were more precise and more like a checklist, this would enable greater differentiation between establishments. It would have been interesting to observe the scores given by each visitor individually, which was possible for only one establishment (company C's establishment in France) because all the other scores were jointly given after discussions with the entire group of visitors.

An attempt was also made to preserve the strengths of the current system in the new scoring system. The new system also provides the possibility to use the scores to assess the level of process safety in the establishment. With the help of the scores the authority can assess where its surveillance (risk-based surveillance) focus areas should lie and the authority and operators can use the scores when observing the chronological development of an establishment, or when comparing topics. The new scoring system also supports the operator and authority in identifying the root causes of potential future accidents.

Some adjustments have already been made to the scoring system used by Tukes. With respect to Tukes inspections, slight changes of this kind were made during this study in 2010. This change meant that scores could only be given in whole or half numbers (e.g. 3 or 3.5), not fractions (e.g. 3.25 or 3.75), as had previously been possible. This change in procedures also had an effect on the scores given for the study; only whole or half numbers were given for company C's establishments. A change in the scoring was made in 2013 in such manner that management of change was separated from risk assessment, whereas operating instructions and competence and training were combined into a single score. Those changes are consistent with the new scoring method developed in this study.

How might the objectivity of the scoring system be improved?

In the new system, an attempt was made to eliminate or at least minimise the weaknesses of the current system. The objectivity of the method was increased by providing a large number of detailed questions and the scope of the scale applied was reduced from 11 to 4. Such changes offer less scope for differing interpretations between inspectors. In addition, scores are now more closely related to legislative requirements. New inspectors will also find the new scoring system easier to learn.

When observing the differences between the scores given by the inspectors testing the newly developed scoring system, it was borne in mind that the inspectors had cooperated and shared opinions during the inspection. Their opinions may therefore have had a mutual effect on each other. The inspectors gave identical responses to 77% of the test's 225 questions, which is a fairly high result. It can be assumed that the number of identical answers would have been lower, if the inspectors had performed the inspections separately.

The inspectors testing the scoring form gave valuable feedback on the form's development needs. It is clear that changes will be required before using the form as a tool in all Seveso inspections in Finland, particularly for self-assessment by personnel of the various establishments involved. The comments made by the inspectors included the following:

- In the case of few questions, it is difficult to exceed the requirements (measurement of this is difficult). In such cases, it would be better for the scale to include 'good practices' rather than 'exceeds the requirements'.
- In the case of few questions, it was unclear precisely what was being asked by the question – a fuller description of the matter is necessary.
- Some questions need additional definition in order to eliminate the possibility of diverging interpretations.
- In the tested version, the 'meets the requirements partly' -indicator covers too large an area: there can be only one small deficiency, or many larger ones.

- A couple of questions should be moved under another heading.

In general, the inspectors involved in testing the method gave positive feedback on the development work. They agreed that the current method required development and is now moving in the right direction. The current method has a much broader set of scales for scoring and the inspectors felt that some thought should be given to widening the scoring scale used based on the new method.

If Tukes aims to adopt this scoring method, it must develop the questions in such a way as to eliminate the possibility of divergent interpretations. Consideration should also be given to whether the number of questions is correct: too many questions would be impossible to answer during an inspection, while too few would provide too little information on the establishment. There is also a need for orientation in using the form and for a written guide on how to use the method, particularly if it is used as a self-assessment tool.

The objective of testing reliability is to ensure that, in situations where another researcher conducts the same study and follows the same procedures as those described by a previous researcher, the same findings and conclusions are arrived at. The goal of reliability is to minimise the errors and biases in any study. (Yin 2009 p. 45) The level of inter-auditor agreement (77%) suggests that the reliability of the tested score system is fairly high.

In all of the inspections, one of the inspectors was more familiar with the establishment than the other (had conducted inspections there earlier, or handled the establishment's permits/ safety reports etc.). Such inspectors had more information on the process safety procedures and may have been able to answer based on data other than that given during the inspection. That may have led to differences in opinion, particularly in cases where one inspector had previous information on the establishment and the other did not answer at all or answered N/A.

The inspectors involved in inspection 5 reported that the assessments were difficult to make due to timetabling difficulties during the inspection. Several current and important issues (corrective actions after an incident) were discussed during the inspection, due to which actual inspection topics received little attention.

Validity refers to whether or not the indicators measure what we think they do. In this section of the study, it is assumed that the tested method measures the level of process safety in inspected establishments. The method is based on the approach currently taken by the authorities, which has been in use since 2005 and is in turn based on the requirements of the Seveso Directive. It is generally assumed that the current method fulfils the aim of the Directive well in preventing major accident hazards involving dangerous substances and enhancing process safety management. On this basis, we can further assume that the new method tested for this thesis is also highly valid. Feedback from the inspectors testing the method supports the view that the method has been developed in the right direction.

Could the improved scoring system lower the work load involved in writing inspection reports?

In Finland, it was often felt that inspection reports were too cumbersome and too long (from the perspective of both the inspectors and the establishments). Reporting and registration work performed after an inspection often takes several days. In addition, the content of the reports is often criticised as failing to serve the establishment concerned. Development work in this respect should begin with a definition of the purpose of the report. It should be possible to develop the reporting of inspections with the help of the new scoring system, since a great deal of process safety information is contained in the scoring table itself. Inspection reports could be e.g. lighter and include the scoring table used.

It should be borne in mind that inspection reports are public documents. Anyone can ask to see an inspection report on any establishment. If such a request is made, the competent authority must hand over the report. The author observes that not all operators are aware of this because the reports are rarely seen by outsiders. Demand for access to reports is likely to increase as, say, the media or establishments and neighbouring communities realise that such reports are public. The Seveso III Directive will probably improve the level and quality of public information in this regard. Inspection reports may also have to be made electronically available on the website of the competent authority. The current reporting system will have to be reviewed before such a change is made.

The author is of the view that the reports sometimes contain information which could be considered classified. Such information could cause harm if it reaches competitors or people who wish to harm the establishment. Classified information of this kind might include the following:

- Unpublished plans on future development projects (especially within listed companies)
- precise information on the processes in question (temperature, pressure, used formula etc.)
- precise information on the location of certain chemicals, expensive raw materials or products on the site
- the security systems of the establishment

When writing reports, inspectors should remember to omit classified information, even if such information is discussed during the inspection and affects the establishment's scoring practices.

Could the improved scoring system be used as a self-assessment tool by operators?

The scoring system was also tested by the operators of the establishments in which the inspectors tested the system. The results of these self-assessments can be seen in the table in Appendix D: Test results of the scoring system. The test included self-assessments whose scores were systematically higher or lower than the scores given by the inspectors. This phenomenon is likely to arise in the early stages, when the method is new, but the scores for the two types of assessment should converge by the time of the second or third self-assessment.

More guidance from the authority is needed in cases where the system is used as a self-assessment tool as well as during inspections. In addition, pre-filling of the form and advance score-giving by operators for various topics and practices would probably better prepare them for, and facilitate the discussions held during inspections. Furthermore, the scores given by the inspectors could be discussed and justified during the inspections. Based on the current systems, the scores are given afterwards, usually while writing the report. The inspector too could pre-fill some scores prior to the inspection, which could help him or her to prepare.

6 Conclusions

The study revealed many good practices in different European countries. Although the good practices observed during the study could be imported to Finland, this would require action from the authority concerned, Tukes. To make use of the comparative study’s positive observations, Tukes must decide on how to communicate the related information to establishments which it would be relevant. The best way of achieving this would be inspections in which, inspectors hold discussions with the responsible persons. Although guidance would also be possible, we cannot be certain whether it would reach the right targets.

The scoring system developed in this study has many benefits compared to the current system. It provides more information for establishments in the form of more detailed questions and the related answers. The questions are precise and easier to answer for both inspectors and self-assessors which makes it easier to learn how to use the system. Based on the differences between the inspectors’ answers, it can be confirmed that the system provides reliable results (the inspectors gave identical answers to 77% of the 225 questions) without special training. With guidance and practical experience, this reliability rate would probably increase.

The changes between the current and new scoring system were developed and tested during the study. These involved changes in the scoring scale (from an eleven-step - scale to a four-step one); in the number of scores given for each inspection (from seven scores to 67) and in the way in which scores are given. The score given for each topic is currently the average score covering a fairly large field of operations, whereas in the case of the system being developed a range of detailed questions must be answered and scored under each topic. The new system seems able to provide the inspectors (particularly new inspectors) with more support, with good results being achieved in terms of the consensus between auditors. The testing of the new scoring system led to positive feedback on development work the inspectors seem open to improvements and new procedures.

If the developed and tested scoring system is to be adopted by Tukes, it must still be developed based on the experiences gained during testing. The inspectors gave feedback on the questions and system itself, which proved useful in the development work. The introduction of the new system would also require a written guide on how to use the new form. Inspectors would need training in using the scale and method, which would best be approached by working in pairs to begin with (in the same way as during the testing phase).

When the new scoring form was being tested, each site tour was given its own heading and questions. However, each question was gathered under another heading so that the score given could be taken into account when giving the average score for the heading in question. Consideration needs to be given to whether the site tour should be given its own average, or the scores should be calculated under the headings which the question concerns, based on the shared opinions of the inspectors. For example, the question on the work permit system is organised under heading 6: Operating instructions, competence and training. The author shares the opinion of many of the inspectors that the site tour is as much about verifying the issues recorded in the documents and reported at an earlier stage of the inspection, as it is about discovering new information. It would therefore be logical to arrange the scores under other various headings and the related scores, rather than giving the site tour its own average score. For example, the work permit system is assessed using two questions at separate stages of the inspection: under heading 6 when examining the documents on the principles of work permit system and during the site tour when inspecting an example of an implemented work permit. Both questions should therefore affect the score given under heading 6.

If the scoring system is renewed, the inspection report should be renewed at the same time. The scoring form should be used as an effective means of reporting and reiteration of the same information should be minimised: if the information is contained in the form, it does not need to reappear in the report. The report could be changed in order to describe the general level of process safety and ways in which the operators could improve this, as well as covering all of the relevant regulations and recommendations.

Tukes already uses risk-based surveillance, which means that – based on the process safety level of the establishment concerned (the scope of activities, accidents that have occurred, scores based on inspections) - the frequency of inspections can be determined. By developing the current inspection assessment system, Tukes will be providing support for its own risk-based review.

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Appendix A: Agenda of the visits undertaken for the study

1. **Opening the meeting and introducing participants**
2. **Introduction to the project**
3. **Establishment and its operations**
   - main chemicals, processes, layout
   - number of personnel, own and outside workers
   - location, operations in neighbouring industrial areas, distance from housing
4. **Recognition of the demands of legislation**
   - permits from other authorities
   - safety report and its conclusions
   - reporting duties to authorities
   - inspections from authorities
5. **Management and personnel commitment**
   - the systems to which the company is committed (quality, environmental and safety management system)
   - safety targets and aims, measurement and handling the results (eg accidents, near-misses, leaks, ignitions in 2008)
   - safety and auditing reports regarding human safety and the natural environment (essential findings)
   - management's processing of safety issues
   - persons in charge: person responsible for operational principles, other responsible persons
6. **Risk assessment and management of change**
   - danger/ risk management (general)
     - How dangerous hazards and their consequences are systematically assessed? When have the assessments been carried out? What are the biggest risks?
     - With what kind of methods are used to identify the dangers and to assess their consequences?
     - Who carries out the assessment?
     - How are the assessments carried out and how often are they updated?
     - How are deviations or information about accidents in other companies handled?
     - How has explosion protection document (ATEX) been handled?
     - Have calculations been made for safety distances/ contours?
   - Management of change

- In which way do you assess dangers relating to changes (technical changes, operational methods and changes in instructions)?
- With regard to the responsibilities relating to changes, who accepts the changes to be implemented and to be put into practice?
- How are the results of risk or hazard assessments taken into account in decisions relating to safety? How have the results affected the layout or the choice of process methods or equipment?

7. Identification of safety requirements

- Technical requirements and condition of the equipment
  - What is the basis for technical requirements for chemical storage tanks (legislation, standards, guidelines for the sector, properties of chemicals, process conditions, risk assessments etc.)?
  - Bunds for chemical tanks, extinguishers , collection of fire-fighting water
  - periodical inspections of tanks
  - plans for maintenance and their realization
  - periodical inspections of electrical equipment
- Operating instructions
  - regulations concerning the safe operation of the plant, maintenance, downtime and deviation situations (and the basis for the content of the regulations) and instructions for updating rules and regulations
  - work permits
    - the kind of work that requires a permit
    - practical methods for dealing with work permits
    - the person(s) responsible for issuing work permits
    - safety assurance prior to issuing a work permit
    - procedures for assuring a safe work environment prior to starting work
    - procedures for following up the progress of the work and its conclusion
    - examples of granted work permits
  - whether the given procedures and methods have been carried out
- Competence and training
  - the way in which the personnel and subcontractors are inducted into their work and duties
  - defined competence requirements for the tasks

        - ensuring that personnel and subcontractor personnel have safe work practices
        - keeping a training register

8. **Emergency preparedness**
    - a definition of what constitutes a deviation
    - the point at which emergency operations are commenced (for example emergency shutdowns)
    - instructions for handling deviations and emergency situations
    - internal emergency plan and its realization and keeping them updating
    - practice and training for states of emergency
        - frequency of drills with the rescue services
        - frequency of in-house drills
        - rescue service co-operation with the establishment at the drills
        - processing the outcome of the drills
    - accident reporting to the Authorities (procedures)
    - deviation reports: the way in which information is collected and utilized
    - distributing information to general public
9. **On-site tour (choosing a certain part of the site)**
10. **Summary**

Appendix B: Current criteria for scores given during Seveso inspections in Finland

Evaluation of company's actions	**Risk factors**			**Good practices**		
	Serious deficiencies **0**	**Significant deficiencies** **1**	**Need for development** **2**	**Fairly good** **3**	**Good practices** **4**	**Proactive development** **5**
Recognition of the requirements of legislation	Negligent attitude No awareness of requirements of legislation No permits from the authority	Only some of the requirements of legislation are understood Technical inspections required by legislation are lacking Easiest options sought	Requirements of legislation are understood Legislative reforms are not systematically monitored No persons in charge	Legislation is well understood, and applied and followed actively	Demands for safety are more comprehensive than legislation requires Own system for following up periodic technical inspections	Takes part in development work on legislation Actively influences safety issues

Evaluation of company's actions	Risk factors			Good practices		
	Serious deficiencies **0**	**Significant deficiencies** **1**	**Need for development** **2**	**Fairly good** **3**	**Good practices** **4**	**Proactive development** **5**
Management and personnel commitment	Management isn't interested in safety Management does not provide resources for handling of safety issues Common rules are not followed	Management is not interested in safety No named persons in charge of safety issues	Management is not visible in production Safety issues are not handled regularly Instructions exist but are not observed	Safety issues are handled regularly Named persons in charge Safety walks	Management is highly visible in production, e.g. in safety walks Also proactive metrics for measuring safety Metrics include contractors	Management develops safety issues Safety targets are visible in daily actions
Risk assessment and management of change	No identification of hazards No risk assessment	Identification of hazards only at a general level Risk assessment incomplete	Dangers identified Risk assessment incomplete Assessments have no effect on decision- making	Dangers identified Risks assessed Planning and decision- making are based on risk assessments	Proactive identification of hazards and assessment of risks Risk assessment supported and part of daily work Assessments are used for developing instructions	Risk assessment involves all operations Risk assessments also required from sub-contractors

Evaluation of company's actions	Risk factors			Good practices		
	Serious deficiencies **0**	**Significant deficiencies** **1**	**Need for development** **2**	**Fairly good** **3**	**Good practices** **4**	**Proactive development** **5**
Emergency preparedness	Near misses or deviations are not documented or handled Negligent attitude towards near misses or deviations No reporting to Tukes about accidents on site	Near misses and deviations are documented but not handled	Near misses and deviations are documented and handled Their effects are not evaluated	Good handling of accidents and near misses Required safety plans are drawn up, updated and rehearsed e.g. internal emergency plan Accidents are reported to Tukes	All deviations are handled openly during periodic inspections Personnel are encouraged to report all near misses and are accustomed to developing operations Simulations are carried out with regard to deviations and feedback is given openly	Deviations and near misses among subcontractors are included in risk assessment Subcontractors take part in drills

Evaluation of company's actions	Risk factors			Good practices		
	Serious deficiencies **0**	**Significant deficiencies** **1**	**Need for development** **2**	**Fairly good** **3**	**Good practices** **4**	**Proactive development** **5**
Competence and training	No requirements regarding competence	Competence requirements are not updated or monitored No training	Training for own personnel Training not planned or documented Subcontractors not involved Requirements for visitors also in place	Qualifications and competence in accordance with requirements Induction programme for new workers and subcontractors Training programme followed	Competence enhancement and participation in training is supported	Systematic training programme for safety and competence Evaluation of competence requirements Subcontractors also involved

Appendix B: Current criteria for scores given during Seveso inspections in Finland

Evaluation of company's actions	**Risk factors**			**Good practices**		
	Serious deficiencies **0**	**Significant deficiencies** **1**	**Need for development** **2**	**Fairly good** **3**	**Good practices** **4**	**Proactive development** **5**
Operating instructions	Dangerous actions Serious mistakes regarding installations Neglecting to check own work	Actions based on experience, not instructions No instructions on use	Some deficiencies in instructions for use and their updating	Observance of procedures and instructions is monitored and deviations are identified and eliminated	Observance of procedures and instructions is monitored and they are developed to enhance safety Deviations are identified and eliminated	Regular risk assessment of operations Procedures and instructions are checked All employees are trained in safety procedures in the area Subcontractors committed to same principles

Appendix B: Current criteria for scores given during Seveso inspections in Finland

Evaluation of company's actions	**Risk factors**			**Good practices**		
	Serious deficiencies **0**	**Significant deficiencies** **1**	**Need for development** **2**	**Fairly good** **3**	**Good practices** **4**	**Proactive development** **5**
Technical require-ments	No directions on the purchase or use of equipment Everyone does whatever he/she wants Inspections carried out only after coercive measures have been taken	Inspections carried out only after resistance Maintenance is reactive only	Maintenance plans not comprehensive Documentation on maintenance incomplete or inadequate	Maintenance plan exists and monitoring documented Safe lay-out and safety distances taken into account Inspections required by legislation are observed Safety require-ments taken into account when purchasing equipment	Proactive mainte-nance Results of mainte-nance and inspections used to develop operations	Top level of technical safety achieved Operator has own comprehensive, internal standards, which includes requirements in excess of legislative requirements
Tukes' actions	*Immediate procedures demanded.*	*Prompt procedures demanded.*	*Request for improvements.*	*Compliance of operations noted. Suggestions for improvements made.*	*Positive practices noted. Enhancements recommended.*	*Recommendation to continue with good work and to share know-how on site.*

(Tukes 2009)

Appendix C: Form used for testing the new scoring method

	0	1	2	3	N/A
	Does not meet the requirements	**Meets the requirements partly**	**Meets the requirements**	**Exceeds the requirements**	**Not applicable**
1.Recognition of the demands of legislation					
Follow-up of changes in legislation, reactions to such changes (methods, practices)					
Updating of permits from authorities, including legislative changes (safety, environmental, buildings)					
Awareness of permits and their terms and when must apply for a permit/ make a notification of a change					
Updating of safety report/MAPP document and its content					
Actions due to recommendations from previous inspection					

	0	1	2	3	N/A
Follow up of requirements from other authorities (rescue services, occupational health and safety, environmental protection)					
Appointing responsible persons (chemicals, LPG, natural gas) and their assigned responsibilities					
Other assigned responsibilities (e.g. rescue equipment, pressure vessels, electrical equipment, transport of dangerous goods)					
2. Process safety management					
Safety goals (indicators), safety policy					
Dealing with process safety in different situations					
Handling the results of external safety audits					
Handling the results of internal audits and management reviews					
Demands for outsourced personnel (contractors etc.)					
Setting process safety indicators, also leading (goals, measuring, follow-up of actions)					

	0	**1**	**2**	**3**	**N/A**
Monitoring of and reactions to process safety indicators					
Safety issues in job descriptions					
Handling of safety observations and near misses					
Incidents concerning dangerous chemicals and their handling					
Cooperation between companies					
3. Identification of danger and risk assessment					
Identification of danger and risk assessment using applicable methods					
Assessments cover all functions including deviations					
Assessments also cover subcontractors					
Assessments have been updated					
Handling the results and observations of assessments					
Distribution patterns and analysis of consequences					
Content and updating of document on protection against					

	0	1	2	3	N/A
explosions (EX)					
Identification of danger and risk assessment of neighbours					
Risk management of domino effect					
4. Management of change					
Defining the changes (size of change, plus temporary and organisational changes)					
Agreed procedures during a change, it's acceptance and implementation					
Risk assessment in planning of change					
The roles and responsibilities of responsible persons during changes					
5. Technical requirements and condition of equipment					
Equipment requirements					
Safety distances and constructions (layout)					

	0	**1**	**2**	**3**	**N/A**
Requirements related to buildings (entrance, selection of materials, explosion-proof structures, fire compartments, control room etc.)					
Applicability and design of air conditioning					
Control of leakages (outdoors, indoors)					
Labelling of rooms, equipment and piping					
Traffic and access control					
Detection and alarms for dangerous situations: detectors for leakages and fire, extinguishing systems					
Control systems and security systems					
Preventive maintenance of safety critical devices and control systems (planning, program, functionality), extinguishing and cooling equipment, gas detectors, emergency showers, diesel generator, overfill preventers, water curtains etc.					
Periodical inspections and self-monitoring (pressure vessels, electrical equipment, chemical pipes, bunds for tanks, automatic extinguishing systems etc.)					

	0	1	2	3	N/A
6. Operating instructions, competence and training					
Working instructions: coverage, updating, safety issues					
Confirming the competence of contractors, instructions and control of operations					
Work permit policy					
Criteria for new employees					
Introductory briefing for new employees					
Safety training (chemicals and their dangers/ accidents, fire extinguishing, occupational safety card etc.)					
Confirming the competence of personnel with training					
Presence of competent personnel (control in emergencies)					
7. Emergency preparedness					
Internal emergency plan and its updating					
Operational instructions for deviations and emergencies					

	0	**1**	**2**	**3**	**N/A**
Handling of accidents					
Follow-up and handling of process incidents					
Internal training (actions in cases of leakage etc. incidents, fire extinguishing, deviation)					
Training alongside rescue services					
Cooperation within the industrial area (principles and practices)					
Notification from the safety report to the neighbouring area					
Design of extinguishing and cooling water					
Collection of extinguishing water					
8. Site tour (no separate score)					
Order and cleanliness (heading 2)					
Labelling (heading 5)					
Procedures related to implemented changes (do they meet the requirements?) (heading 4)					

	0	**1**	**2**	**3**	**N/A**
Principles in practice (documents, following instructions etc.) (heading 2)					
Introduction to control room and interview of personnel (heading 2)					
Introduction to work permit system, including examples (heading 6)					
Total (number of scores)					

Appendix D: Test results of the scoring system

* i=inspection, a=assessor, s-a= self-assessment, empty= N/A or not assessed

	i1 a1	i1 a2	i1 s-a	i2 a1	i2 a2	i2 s-a	i3 a1	i3 a2	i3 s-a	i4 a1	i4 a2	i4 s-a	i5 a1	i5 a2	i5 s-a	Avera ge
1.Recognition of the demands of legislation																
Follow-up of changes in legislation, reactions to changes	1	0	1	2	2	2			2	2	2	1	2	1	2	1,54
Updating of permits from authorities, including based on changes	2	2	2	2	2	1	2	2	2	2	2	2	1	2	2	1,87
Awareness of permits and their terms…	2	2	2	1	2	2	2	2	2	2	2	1	1	2	2	1,80
Updating of safety report/ MAPP document and its content	1	1	2	1	1	0	2	2	2	2	2	1	1	2	1	1,40
Actions in response to recommendations from previous inspection	2	2	2	2	2	1			1	2	2	1	1	2	1	1,62
Monitoring of requirements from other authorities	2	1	2	2	2	2			2			2	2	2	2	1,91

	i1 a1	i1 a2	i1 s-a	i2 a1	i2 a2	i2 s-a	i3 a1	i3 a2	i3 s-a	i4 a1	i4 a2	i4 s-a	i5 a1	i5 a2	i5 s-a	Average
Appointing responsible persons and assigning their responsibilities	1	1	2	2	2	2	2	2	2	2	2	1	2	2	2	1,80
Other assigned responsibilities	2	2	2	2	2	2	2	2	2			2	2	2	2	2,00
Average	2	1	2	2	2	2	2	2	2	2	2	1	2	2	2	1,7412
2. Process safety management																
Safety goals, safety policy	1	2	2	2	2	2	2	2	2			1	1	1	1	1,62
Dealing with process safety in different situations	0	1	3	1	1	1	2	2	2	2	2	2	1	1	2	1,53
Handling the results of external safety audits	1	1	2	1	1	2			1			2	2	2	2	1,55
Handling the results of internal audits and management reviews	1	2	2	1	1	2			1	2		1	2	2	2	1,58
Demands for outsourced personnel	1	2	3	2	2	2			2			1	2	2	1	1,82

	i1 a1	i1 a2	i1 s-a	i2 a1	i2 a2	i2 s-a	i3 a1	i3 a2	i3 s-a	i4 a1	i4 a2	i4 s-a	i5 a1	i5 a2	i5 s-a	Avera ge
Setting process safety indicators	0	2	3	1	1	1	2	2	1	0	0	0	1	0	2	1,07
Monitoring of and reactions to process safety indicators	0	1	3	1	1	2	1	1	1			0	1	1	2	1,15
Safety issues in job descriptions	1	1	1	2		2			2			2		2	1	1,63
Handling of safety observations and near misses	2	2	3	2	2	2	2	3	3	1	1	2	2	2	2	2,07
Incidents concerning dangerous chemicals and their handling	2	2	2	2	2	2	1	1	2	2	2	2	2	1	2	1,80
Cooperation between companies	1	1	2	2	2	2			1			1			3	1,50
Average	1	2	2	2	2	2	2	2	2	1	1	1	2	1	2	1,573 44
3. Identification of danger and risk assessment																

	i1 a1	i1 a2	i1 s-a	i2 a1	i2 a2	i2 s-a	i3 a1	i3 a2	i3 s-a	i4 a1	i4 a2	i4 s-a	i5 a1	i5 a2	i5 s-a	Average
Identification of danger and risk assessment using applicable methods	1	1	2	2		2	2	2	2			1	2	1	2	1,67
Assessments cover all functions	1	1	1	2	2	2			2			0	0	1	2	1,27
Assessments also cover subcontractors	1	1	1	1	1	2			2			0	2	2	1	1,27
Assessments have been updated	1	0	1	1		1			1			1	2	1	1	1,00
Handling the results and observations of assessments	1	0	1	1		1			1			1	2	2	2	1,20
Distribution patterns and analysis of consequences	0	0	2	2		2			1			1	1	1	1	1,10
Content and updating of document on protection from explosions	1	0	2			2			2			2		2	1	1,57
Identification of danger and risk assessment of neighbours	0	1	1	2	2	2	2	2	2			1			2	1,50
Risk management of domino effect	0			2	2	2			1			0		2	2	1,29
Average	1	1	1	2	2	2	2	2	2			1	2	2	2	1,318

	i1 a1	i1 a2	i1 s-a	i2 a1	i2 a2	i2 s-a	i3 a1	i3 a2	i3 s-a	i4 a1	i4 a2	i4 s-a	i5 a1	i5 a2	i5 s-a	Average
																81
4. Management of change																
Defining the changes	1	1	2	1		1	1	2	2			1	1	2	1	1,33
Agreed procedures during a change, its acceptance and implementation	1	0	2	1		1	1	1	2			1	2	2	1	1,25
Risk assessment during planning of change	0	1	2	2	2	2			2			1	1	1	1	1,36
Roles and responsibilities of responsible persons in relation to changes	1	1	1	1	2	2	1	1	2	2	2		1	2	1	1,43
Average	1	1	2	1	2	2	1	1	2	2	2	1	1	2	1	1,343 89
5. Technical requirements and condition of equipment																
Equipment requirements	1	2	2	2		2			2			1	1	1	1	1,50
Safety distances and constructions	1	1	2	1	2	2			2			1	1	2	1	1,45

	i1 a1	i1 a2	i1 s-a	i2 a1	i2 a2	i2 s-a	i3 a1	i3 a2	i3 s-a	i4 a1	i4 a2	i4 s-a	i5 a1	i5 a2	i5 s-a	Average
Requirements related to buildings	1	2	2	2	2	2			2			1	1	2	2	1,73
Applicability and design of air conditioning			2	2	2	2			2			1	1		2	1,71
Control of leakages	1	1	2	1	1	2	2	2	2			1	2	0	1	1,38
Labelling of rooms, equipment and piping	1	2	2	1	1	1	1	1	2	1	1	1	2	1	1	1,27
Traffic and access control	2	2	2	2	2	2	2	2	2	1	1	2	1	2	3	1,87
Detection and alarms in dangerous situations…	2	2	2	2	1	2	2	2	2	2	2	2	1	0	2	1,73
Control systems and security systems		2	2	1	2	2			2			2	1		2	1,75
Preventive maintenance of safety critical devices and control systems...	2	2	2	1	2	2	2	2	2	2	2	1	1	0	2	1,67
Periodical inspections and self-monitoring	2	2	2	2	2	2		2	2	1	1	2	1	0	2	1,64
Average	1	2	2	2	2	2	2	2	2	1	1	1	1	1	2	1,60972

	i1 a1	i1 a2	i1 s-a	i2 a1	i2 a2	i2 s-a	i3 a1	i3 a2	i3 s-a	i4 a1	i4 a2	i4 s-a	i5 a1	i5 a2	i5 s-a	Average
6. Operating instructions, competence and training																
Working instructions: coverage, updating, safety issues			2	2	2	2			2			1	2	2	2	1,89
Confirming the competencies of contractors, instructions…			2	2	2	2	2	2	2	2	2	1	2		1	1,83
Work permit policy			2	2	2	2			2	1	1	2	2	2	1	1,73
Criteria for new employees			2	2		2			2			2	2		2	2,00
Introductory briefing for new employees			2	2		2			2			1	2		2	1,83
Safety training			2	2	2	1	2	2	2	1	1	2	2	2	2	1,77
Confirming the competencies of personnel based on training			2	2	1	1			2			2	2	1	2	1,67
Presence of suitably skilled personnel			2	2	2	1			2			2	2	1	3	1,89

	i1 a1	i1 a2	i1 s-a	i2 a1	i2 a2	i2 s-a	i3 a1	i3 a2	i3 s-a	i4 a1	i4 a2	i4 s-a	i5 a1	i5 a2	i5 s-a	Average
Average			2	2	2	2	2	2	2	1	1	2	2	2	2	1,825 95
7. Emergency preparedness																
Internal emergency plan and it's updating	2	2	2	2	2	1	2	2	2			2	1	2	2	1,85
Operational instructions in the case of deviations and emergencies			2	2	2	1			1			2	1	2	2	1,67
Handling of accidents	2	2	2	2		2			2	2	2	2	1	2	2	1,92
Follow-up and handling of process incidents	2	2	2	2		2			2			1	1	0	2	1,60
Internal training	1	1	1	2	3	1	2	2	2	1	1	2	1		2	1,57
Training alongside rescue services	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	1,87
Cooperation in the industrial area	1	1	2	2	2	2			2			2			2	1,75
Notification based on the safety report for the neighbouring area	2	2	2	2	2	2				3	3	2		2	2	2,18
Design of extinguishing and cooling water	2	2	2	1	1	2			2			1		0	1	1,44

	i1 a1	i1 a2	i1 s-a	i2 a1	i2 a2	i2 s-a	i3 a1	i3 a2	i3 s-a	i4 a1	i4 a2	i4 s-a	i5 a1	i5 a2	i5 s-a	Average
Collection of extinguishing water	2	2	2	1	1	1			1	2	2	1	1	0	1	1,31
Average	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	1,715 15
8. Site tour																
Order and cleanliness	3	3		1	1								2	1	2	1,83
Labelling	2	2		1	1								1	1	1	1,33
Procedures related to implemented changes	1	1		2									2		2	1,50
Principles in practice				2	2								2	2	2	2,00
Introduction to control room and interviewing of personnel		2		2	2								2			2,00
Introduction to work permit system based on an example				2	2											2,00
Average	2	2		2	2								2	1	2	1,78
Average for all questions	1.3	1.4	1.9	1.7	1.7	1.7	1.8	1.9	1.8	1.7	1.7	1.3	1.5	1.4	1.7	1,62

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