

# An Environmental Risk Management Framework for a Nordic Construction Firm

A Stakeholder Oriented Model  
for Veidekke Entreprenør AS

ATISH BAJPAI



**KTH Chemical Engineering  
and Technology**

**Master of Science Thesis  
Stockholm 2006**





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Supervisor: Hege Hansesveen

Examiner: Björn Frostell

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Stockholm, May 2006

*Atish BAJPAI*

## Abstract

Construction is one of the oldest of industries in the world, with the first established construction company being established around 230 BC. One of the biggest industries in Europe, at an estimated €900 billion a year, it also accounts for 40% of total energy consumption and 40% of total waste generation in the EU<sup>1</sup>. Although the majority of these are from the use phase of the built environment, there is a lack of a comprehensive environmental risk management system for the construction phase. This study proposes an environmental risk management framework based on the Beer-Ziolkowski model of risk management for both site specific and non-site specific construction operations with a stakeholder centric approach. It proposes stakeholder involvement to identify the risks aided with trend analysis of strategic regulatory implications from the concerned authority - Norwegian Ministry of Local Government and Regional Development and the current organisational practice of objective environmental risk identification from ISO 14001 guidance. Scope of site specific and non-site specific risks are narrowed down to site operational setup and construction materials respectively, consistent with the organisations view of the most important risks from those two classes of risks. Risk assessment is suggested through Fault Tree Analysis (FTA) method for site specific risks and European Union System for the Evaluation of Substances (EUSES) for non-site specific risks. Total Cost Accounting (TCA) of project alternative evaluation is recommended with a view to internalise the external costs. A two tiered integration of risk information in the buisess process is suggested – categorised risk reduction process at the level of projects and general good practice aided with risk information at the policy level. Being a framework for management of environmental risk as opposed to a method for a specific environmental risk, the principles and suggestions are broadly scoped with case studies for identification and analysis of risks.

Through the practice of prudent engagement of stakeholders and scientific risk assessments, this framework would help the organisation enable safer operational practices in the context of environmental effects. In foresight this in turn will have rendered the host firm more competent in terms of making sustainable business decisions.

**Keywords:** Environmental management system, environmental risk management, construction industry, stakeholder deliberation, FTA, EUSES, TCA, ALARP.

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<sup>1</sup> European Agency for Safety and Health at Work, “Good Practice: Construction,” 2003;  
[http://europe.osha.eu.int/good\\_practice/sector/construction](http://europe.osha.eu.int/good_practice/sector/construction)

## Sammanfattning

Byggindustrin är en av de äldsta industrierna i världen. Det första företaget etablerades ca 230 BC. Byggindustrin är även en av de största industrierna i Europa med €900 miljarder i omsättning varje år, men ansvarar även för ungefär 40% av energiförbrukningen och 40% utav den totala avfallsgenereringen i EU<sup>1</sup>. Trots att det mesta av dessa miljöfarliga aspekter kommer ifrån användningsfasen av den byggda miljön, finns det en brist på omfattande hanteringssystem för miljörisker vid uppbyggnadsfasen. Denna studie föreslår en hanteringsmodell, baserad på Beer-Ziolkowski-modellen för riskhantering, som innehåller både byggplats baserade och icke-byggplats baserade risker med en centrerad orientering vid just aktieägare samt andra berörda.

Denna modell föreslår, att alla som skulle bli berörda vid förändring, engagerar sig för att identifiera risker med assistering utav strategisk vägledning hos den lämpliga förvaltningen - *Kommunal- og regionaldepartementet* samt med det närvarande organisationspraxisen av indentifiering av de objektiva miljöriskerna med råd ifrån ISO 140001. Omfattningarna av byggplats-beroende och icke byggplatsberoende riskkategorier fokuseras på layouten av byggplats och byggmaterial, enligt företagets åsikt vilken av dessa två riskgrupper som är viktigast. Riskshantering föreslås med felträanalys (FTA) metoden till byggplats beroende risker och European Union System for the Evaluation of Substances (EUSES) till icke byggplats beroende risker. Helkostnadsbokföring (TCA) för projektets olika alternativ rekommenderas som åtgärd för att inkludera de vanliga ytterliggande kostnaderna. En två spårig integration av risksbeskedet föreslås – katagoriserad riskminskning vid projektsnivå och vanliga goda affärsprincipier tillsammans med riskmedvetenhet på policy nivå.

På grund av att modellen är en ram för riskhantering, som skilljer sig ifrån en metod för en särskild risk, granskas priciperna så som föreslaget med fallstudier för identifiering och analys av risker.

Genom att engagera aktieägare och andra intressenter men även natuvetenskaplig riskbedömning, ska denna modell hjälpa företaget till att möjligöra en säker bedrivning utav företagspraxisen i kombination med ett stärkt intresse utav miljöaspekter. I framtiden ska detta i sin tur ge företaget större kompetens när det gäller att planera och skapa en hållbar affärsplanering.

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<sup>1</sup> European Agency for Safety and Health at Work, "Good Practice: Construction," 2003;  
[http://europe.osha.eu.int/good\\_practice/sector/construction](http://europe.osha.eu.int/good_practice/sector/construction)



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*To Bigzy...up away with the diamonds where he is now*

*And*

*The ethereal luminescence of Northern Lights that eternally waft over dark snowy woods of Sweden*





## 1. Introduction

Why is there a need at all for risk management for a construction firm, which is already financially insured against such unforeseen events?

There is no one answer to this question which can address all the different causes contributing to the initiation of such a study. First and foremost, a competent risk management paradigm can systematically help reduce the negative environmental impacts from construction activities [1]. Not only does built up environment create adverse impacts on the natural environment during its use phase but there is substantial risk posed at the construction phase too. The risks at the construction stages have often been outweighed by the use phase risks such as emission or leaching of hazardous substance in construction materials from the built up installations. This is due to the more incidental nature of the construction phase risks and the fact that those incidents can be avoided to a large extent if appropriate measures are taken. On the contrary, the use phase of a building is much longer and often the risks posed by it are not incidental, e.g., inefficient energy design or inappropriate substance use will be chronic problems throughout the life of the building. Thus research has focused more on ensuring safety in the use phase of construction installations. However, a few recent researches have shown clear external environmental costs associated with construction activities and the accidents due to less diligent construction process [2]. Secondly, in the age of market competitiveness a negative image in environmental affairs is extremely detrimental to the company's image to the stakeholders. Thirdly, a clear understanding of the managerial and technical build up that gave rise to an environmental risk paves the way for a more pragmatic and efficient upstream business decision-making, thus lowering the burden on the environmental management system. This aspect is clearly articulated in Veidekke's environmental goals [3]. Finally, given the dynamic nature of the environmental legislations in Norway, as with most of the developed world, the organisation felt the need to proactively initiate a system that could, amongst others, track the changes in the environmental requirements from a construction company. This aim to be ahead of regulations is a precursor to be an organisation with the proactive group (Leading Edge) in the stage model analysis of environmental management systems [4].

These needs and aspirations despite being typical of many comparable construction firms, progress towards developing a comprehensive system that can address these issues has been limited. Two main reasons for this at Veidekke have been – lack of adequate resources, both in terms of capital and knowledge that are available for developing such frameworks [5]. Risk management plans are normally part of Business Recovery Plans (BRP). BRPs provide a certain level of technical insurance in that if a major catastrophe occurs, it will not result in a major financial loss for the organization (ref: Fig. 1) [6].

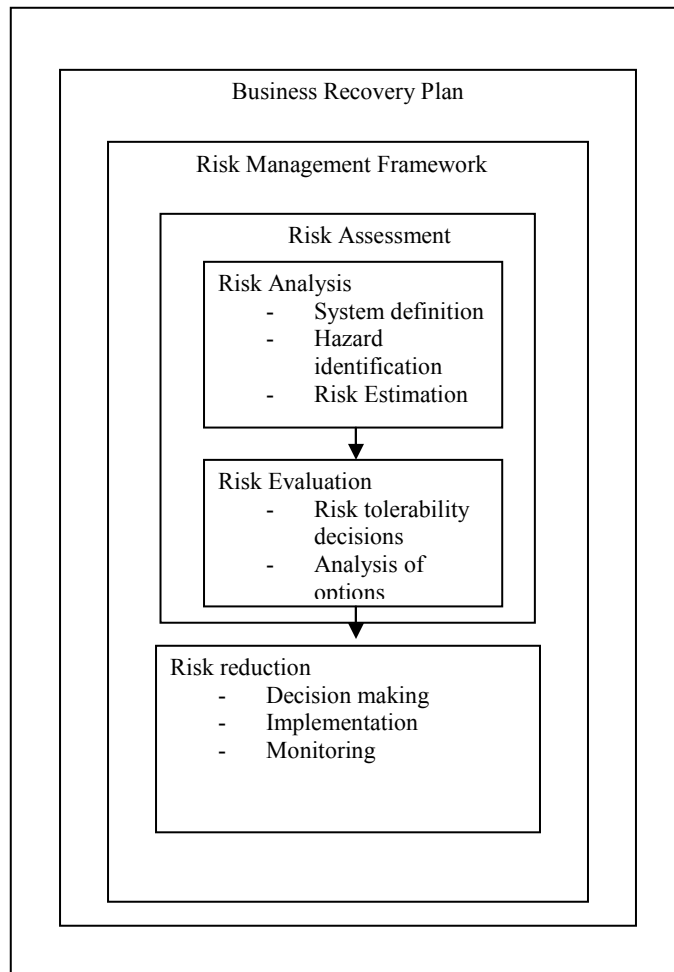


Figure 1. *The Indicative Risk Management Scenario in a BRP context (modified from Center for Chemical Process Safety, AIChE)*

An organisation will certainly have more risks than the risks arising out of the environmental facet, but saying that it has its own weight in the BRP [7]. A recent survey on a large group of Fortune 100 companies showed that on average less than 3% of the annual budget is spent on BRP [8]. This being the case with BRPs for all forms of disasters, it is needless to say how limited is the allocation of finances for environmental risk preparedness. However, due to a combination of several reasons, notably, stakeholder expectations for a more assured and demonstrative way of environmental management, the organisation has now set sights upon developing a risk management framework exclusively for the environment (ref § 2, Part I). The other concern has been the lack of knowledge resources, which is clearly evident from the few frameworks available, which deal specifically with environmental risk, and fewer, virtually non-existent, about applications that do not maintain an exhaustive database of materials used and produced such as the construction industry [1]. Climate change framework and other macro level environmental frameworks, fail to capture the needs for a micro level entity. Simple construction processes such as those for buildings, roads, bridges and tunnels etc.,

which do not imply a potential danger even in the consequence of accidents, largely treat environmental management as a whole, without working any further for environmental risk management as such. For construction industry this in reality does not go any beyond material safety datasheets at project level nor do the firms allocate the wherewithal needed to systematically document the accidents that might have been caused due to an environmental issue, unless concerned beyond a certain threshold of damage, which too is commonly set based on subjective and scientifically untested criteria.

## **2. Aim and Objective**

To find an appropriate framework for dealing with various environmental risks faced by an infrastructure development concern, using cost effective approaches and tools. Being multi-disciplinary in approach, it draws on a range of basic scientific skills to generate data, and a wide array of other skills to communicate, evaluate, interpret, and act on the assessment. It is an integrative study which aims to root the framework conceptually in the BRP of the organisation and functionally in the environmental management system of the company.

The objectives of the study are:

- add transparency and inclusiveness to the decision-making process
- enable a better understanding of various risks related concepts to the staff of the organisation
- ensure that the framework establishes a foundation from where more advanced and benchmarking of environmental risks can be achieved

## **3. Disposition**

This study is divided in two parts, the first detailing the theoretical aspects of the framework and the second elucidating an application of it. Part I starts with a broad description of environmental sustainability aspects in the construction industry and the built up environment as such. Specific causes that necessitated the study for finding an environmental risk management framework are described next. The main tasks of the study are choosing an appropriate risk management framework, modelling it such that it would suit the context from the available ones and specifying each of the components of the framework.

The framework is divided into three operational blocks – identification, analysis and integration of risks. The identification and analysis parts are further elaborated with case studies in Part II of the report.

## **4. Methodology**

Being primarily an exploratory research rather than a case study based deductive study, this study relied heavily on literature and broad overview of the Veidekke's operations. The study is carried out using the following information sources –

- Interaction with personnel in Veidekke, including site visits and communication through different media

- Literature
- Survey

Interaction with directorial-level staff and environmental management staff of Veidekke showed that identification and estimation of environmental risk were of primary importance to the organisation [9]. Formation of technical alternatives whose environmental impacts would need to be evaluated by the framework was left out as that was felt to be outside the purview of the environmental management and more of a technical operation. Initial literature review was presented to the staff and a third step to enumerate appropriate use of the risk information was found to be suggestive from all the frameworks studied (ref § 4, Part I). Accordingly, the following were decided as the operational components of the framework:

- Identification of risk – Various technical and non-technical process of identification of risk
- Analysis of risk – Analysing the risk from technical and non-technical perspectives
- Integration of risk management framework into the overall business process – incorporating the system of risk management into the overall functioning of the firm

While compiling this report, each of these three steps is divided into three stages:

- Stage 1 – Review literature about the processes
- Stage 2 – Select the appropriate process(es) and establish a working relation between them to formulate a framework
- Stage 3 – Apply the process to practical situation (case study)

Table 1: *Working scheme of the thesis*

<b>Process</b> <b>Stage</b>	<b><i>Identify</i></b>	<b><i>Analyse</i></b>	<b><i>Integrate</i></b>
<b>Stage 1</b>	✓	✓	✓
<b>Stage 2</b>	✓	✓	✓
<b>Stage 3</b>	✓	✓	<b>X</b>

NB: *Due to practical constraints of time, it was not be possible to carry out the integration of the risk management framework in the decision process pragmatically. It is thus left for the organisation to implement the framework according to the suggested method in Stage 3 of Integration.*



## **4.1 Data quality and assumptions**

Before the actual study commenced, background discussions about the feasibility of the various recommendations that the framework might suggest, indicated that there could be a lack of appropriate data required for the framework. Basic understanding of risk management suggests a need for probability function involving the environmental impact of an undesired incident and its economic value [10]. The probability functions are mostly statistical operations requiring retrospective reliability information of operational setup. The data for these were not available at Veidekke. Communication with two other major construction firms in Sweden – Skanska Stockholm AB and NCC AB also proved to be unproductive. This impediment was taken as input and rather than designing a quantitative risk assessment process, a semi-quantitative approach, Fault Tree Analysis method was used, that can function with logical operators but can also step up the accuracy with quantitative data, if available.

As the study rolled on, risk evaluation of construction materials needed specific information about eco-toxicity of substances which were difficult to obtain, as only few sources share such data. Although the data for the selected material was available, that cannot be said for all materials on the substance phase out list.

# Part I: CONSTRUCTION OF THE FRAMEWORK

## 1. Sustainability and construction

Need to study sustainability in construction is evident in modern researches. The society consists of various material and energy flows. The balance of these flows is critical for survival of the planet in the long run. Some of the main indicators of long term survival are the emission of Green House Gas (GHG) and waste production, both of which are related to construction industry. There has been a tremendous surge in the number of studies exploring the effects of construction on the environment in the last decade. Approximately a total of 25.6% or roughly a fourth of the country's GHG emissions comes from the different life cycle phases of constructed properties in Norway [11], [12]. Thus the construction sector is critical toward sustainability. Moreover, the GHG emissions from Norway in 2010 are prognosticated to be about 17 % higher than the Kyoto target for a “business as usual” scenario [13].

### 1.1. Principles of Sustainable Construction

Drawing upon the Brundtland Commission findings, environmental sustainability in general has come to be defined in a triple bottom line approach – economic, social and technical. To derive principles of sustainability specific of built environment necessitated a broadening of this triple bottom line to a four pronged ideology where the technical aspect has been further distinguished from a biophysical aspect [14]. The technical principles profess use of sustainability fostering design and implementation of technology whereas the biophysical principles enumerate the mechanisms to control material and energy flows. In construction sector, the choice of technology affects bio-physical equilibrium while the bio-physical conditions indicate what type of technology should be used. As both the aspects are equally important for sustainability, it is only prudent to delineate them separately. These principles are as follows -

- *Social principles of sustainable construction:*
  - By ensuring compatibility with local technology and capacity [15]
  - By incorporating cultural diversity in construction planning [16]
- *Economic principles of sustainable construction:*
  - Full cost accounting and internalising of external costs into the tariffs
  - Adopting pro-sustainable policies in business
  - Liaising with contractors capable of appreciable environmental performance
  - Contribute to the economic throughput driving sustainability
- *Biophysical principles of sustainable construction:*
  - Reducing the use of four most used components in construction – energy, mineral, water and land [17]
  - Reducing waste, by increasing recycling and resource efficiency. This would tie in with the previous principle of using less land as well
  - Using renewable resources as opposed to more easily available non-renewable

- resources. For construction materials this could mean using wood from sustainably managed forests; for energy this can relate to using daylight, solar heating of water and using photo-voltaic methods of generating electricity.
- Minimising or phasing out toxic material from construction

- *Technical principles of sustainable construction:*
  - Prolonging product life cycles, for reasons of energy efficiency and lesser production of waste [18]
  - Moving away from strictly bottom-line oriented design to those allowing modifiability through modularity [19]
  - Using building designs that allow the inhabitants a closer contact with nature. This would include, inter alia – windows that can be opened, thin buildings with less central space

While the above mentioned four overarching principles underpin the sustainable construction process, there are more downstream approaches that are applicable at the level of the process of construction (ref. Fig. 2).

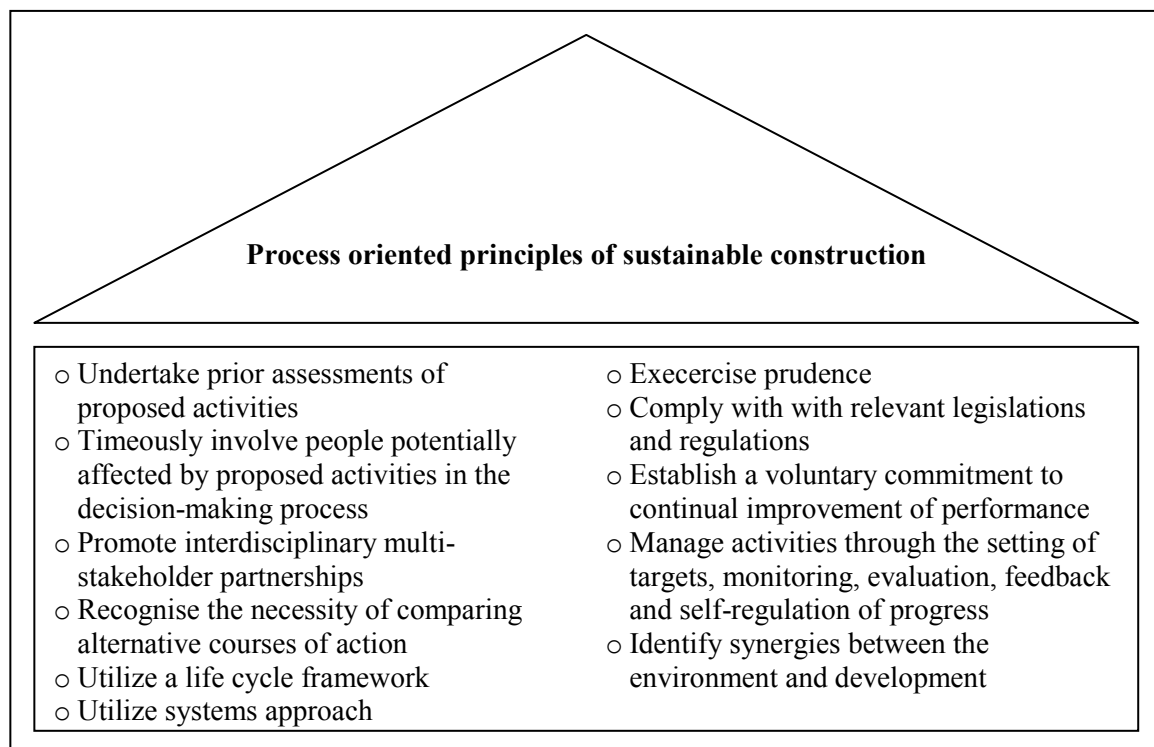


Figure 2. *Process oriented principles of sustainable construction*

Despite industry application of several of these sustainable construction principles, the onus is somehow still not on sustainability but rather on short term objectives such as environmental management that tends to be minimal and construction business processes that do not take into account the long term benefits of investing in environment. There are many reasons that are cited by the industry as to why there is a lack of initiative on the part of construction industries that are proactive in environmental sustainability matters. These include [2] –

- Lack of government support
- High cost of implementing environmental management system (EMS)

- Practitioners lack of understanding of environmental management, thereby an expected complication to grasp the more advanced concepts of sustainability
- Lack of tangible benefits from investing in pro-environmental concerns
- Difficulty in determining environmental costs with an appreciable level of accuracy
- Lack of client demand

In 2003, the National Building Research Institute (Byggforsk) recommended a set of five initiatives for the regulatory authorities to adopt in order to ensure integration of sustainability concerns, particularly energy use in unit level organizations [13]. Some of these are:

- Tightening the energy requirements in building regulations, and
- Introducing a comprehensive grant scheme for improvements in existing buildings.

These initiatives represent a mix of top down and bottom up approaches to drive the integration.

## 1.2. Sustainability and Veidekke

According to the environmental management division, there are four domains where the choices made by a construction contractor like Veidekke can influence sustainability considerations.

- *Location of constructions*

Veidekke is a build-transfer contractor and builds both on plots that are purchased by it as well as those that belong to its customers. The break-up of revenue from these two types are approximately 50% for 2002-2004. Put other way, there is only a limited extent to which it can decide the location of its constructions. In the current practice, pre-approval appraisals of site locations ensure that construction at those places does not harm any of the municipal level environmental legislations. For pre-assigned plots, no further environmental assessment impact is done for construction.

- *Choice of material*

Veidekke is a ISO 9001 certified company and records of the chemicals used in construction are documented according to its guidelines. The prioritising of materials is done in accordance with the list of Ministry of Environment (Miljødepartementet) which has a classification of 3500 substances as harmful to environment and health. Further, 250 of those substances are classified as reduction substances and amongst those 28 are priority reduction substances [20].

- *Energy use*

The amount and type of energy to be used in the residential and commercial buildings done by Veidekke is according to the designs of the architect and electricity design contractor. The designs follow current environmental standards. Veidekke does not play a direct role in this. As a proactive gesture to add to the current inertia of energy efficiency in buildings, Veidekke has started to collect data about energy types being used at its constructions.

Table 2: *Energy usage at Veidekke Entreprenør constructions*

	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>
<b>Total consumption</b>	250 GWh	218 GWh	203 GWh	236 GWh
<b>Gas</b>	16%	10%	21%	23%
<b>Oil</b>	63%	65%	57%	56%
<b>Electricity</b>	21%	25%	22%	21%

Apart from this endeavour that will help Veidekke compare the pattern of energy sources used its constructions with that in Norway over a period of time, it is also involved in OPTIVATØR that will help heating and ventilation during the building phase of the construction. It is also part of “Energy Labelling of Houses” project by SINTEF. Recently, it was decided to initiate discussion with Veidekke’s energy design contractors to introduce a bar on the maximum limit of energy to be used in the design of the buildings. This maximum limit would be at least 10-13% lower than the permissible usage in Norway.

- *Waste generation and treatment*

There is active involvement of Veidekke in the construction waste reduction initiative of Oslo municipality. The organisation currently recycles 40% of its waste on its own with a subsidiary.

Amount, type and source separation of waste are the parameters that are used for efficiency in waste recovery actions.

Table 3: *Waste generation and separation at source at Veidekke*

	<b>2004</b>	<b>2003</b>	<b>2002</b>	<b>2001</b>
<b>Waste generation amount per unit construction</b>	28 kg/m <sup>2</sup>	233 kg/m <sup>2</sup>	225 kg/m <sup>2</sup>	27 kg/m <sup>2</sup>
<b>Separation at source</b>	40 %	30%	28%	24%

Reduction of use of heavy material at construction has seen Veidekke prefer insulation and plastic to plasterboard and wood respectively, though this has increased the price of the buildings. The company also tries to help recycling industries by providing profit sharing dividend with them.

The various aspects of construction chosen by Veidekke to work on present a picture of an organisation striving to ensure sustainability in its operations. However, given the scope of Veidekke’s work as a contractor that does not design the constructions, nor owns the constructions, there is only a limited influence it can wield on the overall sustainable construction scenario, since the design and use phases of built environment last much longer than the construction phase and have a wider and stronger impact on the natural environment [20]. Some of the apparent areas where Veidekke can focus to drive its attention that will contribute substantially and positively on the environment are:

- Ownership of the buildings for a longer period, as opposed to outright sale. This will give the company a greater leverage on controlling the material and energy flows associated with the most important phase of built assets – the use phase.
- Capacity building and knowledge sharing with other construction contractors to discuss the pragmatic roles that can be played by the contractors in bringing in a paradigm shift that would enable the initiation of top-down socio-economic instruments to foster a more sustainability oriented real estate market.

## 2. Background of this study

In August 2005, this thesis commenced in Oslo at the behest of Veidekke Entreprenør AS. Veidekke Entreprenør is the largest shareholder (50%) in the Veidekke group.

It maybe argued that as the construction processes at Veidekke are only the commonly used ones; the type and management of the materials used (construction materials) and produced (construction and other waste) are all within legal limits, what is the point in assessing the risks in them?

This is primarily due to two reasons –

- Preceding background studies (mainly in the form of stakeholder dialogues) in the recent past (2003-2005) had revealed a marked concern among stakeholders about the environmental risks from the operation of Veidekke (ref §1.1, Part II). There was a need to enumerate risks from the use of materials, not only the physico-chemical properties, as given in the existing health-safety-environment data sheets. This was all the more needed when an alternative of a material in environmentally harmful substance class (IUPAC Class – N) also happened to be another material in the same class. This situation is common in Veidekke as well as in any other construction company, as in Scandinavian countries a premium is often put on environmental conservation and had there been a better alternative, e.g., not belonging to the N-class, most definitely that would have been used. In such cases, the only way to scientifically fortify the logic for selecting one above another is based on the risk potential of each of them under identical situations, thus the need to go beyond physico-chemical properties reporting of substances and to build up the expertise for risk assessment procedures.
- The environmental management personnel at Veidekke felt that an added measure of risk assessment done internally and introduced into the organisational culture at Veidekke will bring with itself an inherent pro-environmental momentum that can eventually lead to a greater awareness of the business opportunities in alternative ways that are considered more environment friendly.

Keeping in view the genesis of the thesis, the drivers for this framework are identified as:

*Top down:*

- Need to acquire knowledge of the risks
- Willingness of the management to show commitment
- Need to find a logical base to allocate resources for environmental concerns, vis-à-vis other concerns

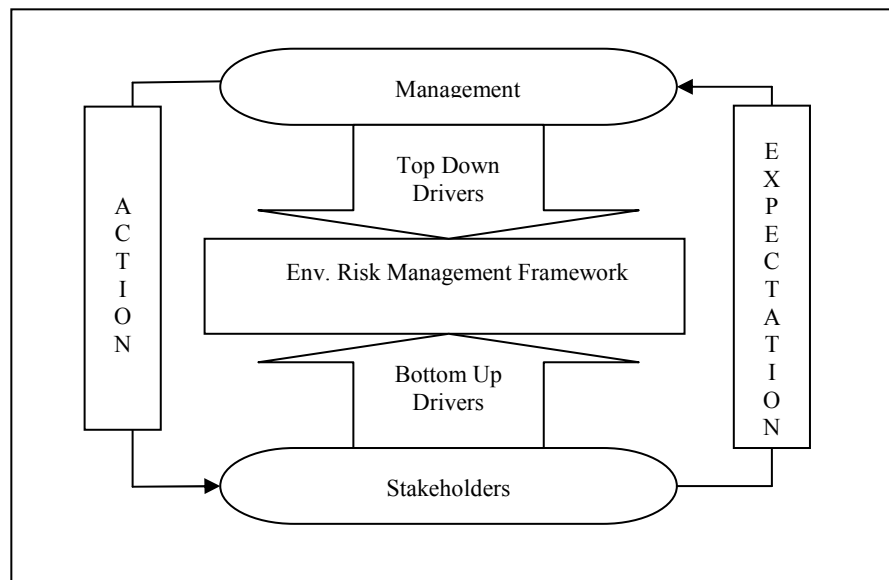


Figure 3: *External setting of the environmental risk management framework*

*Bottom up:*

- Perception and awareness of risk in stakeholders
- Communication of concerns
- Critical appraisal and appreciation of the results of the proactive measures

## 2.1. The role and scope of the proposed environmental risk management framework

The baseline setting for this study is schematically presented in Figure 4.

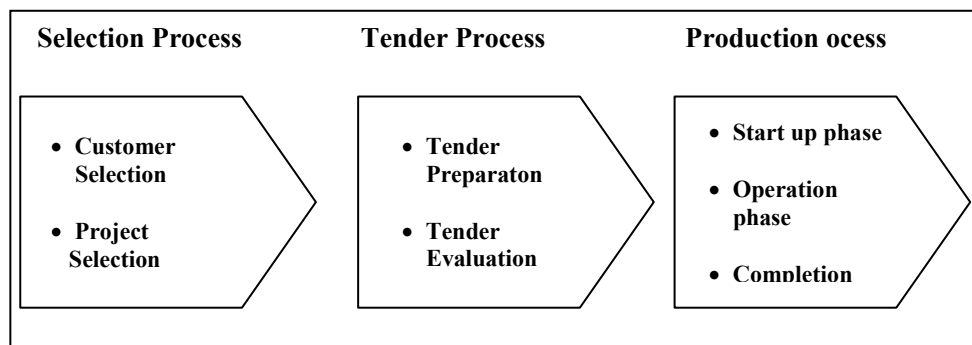


Figure 4: *Project level business process at Veidekke Entreprenør AS*

The environmental works of the company are in two phases that are as follows:

- Selection Process: In this phase the environmental work is identification of important environmental aspects of the project
- Production Process: In this phase a general Plan-Do-Check-Act routine of environmental management is followed

The framework has to work within these operational bounds.

Consistent with the needs of Veidekke, first the principles of the proposed environmental risk management framework were set:

1. To provide a continuum of timely technical assistance to the environmental management system in the company
2. To provide the stakeholders of the company with new and existing information about actual or perceived risks that will help to design appropriate mitigation methods.

Next, the objective goals of the framework were to be set. Generically defined, a framework is an extensible structure for describing a set of *concepts*, *methods*, *technologies*, and *cultural changes* necessary to assist management achieve its goals and objectives [21], [22]. As mentioned in the background to this study, Veidekke felt a framework would be suited to its needs, and thus concepts, methods, technologies and cultural changes – all the components of a framework would need to be translated in such a way that together they make up an environmental risk management framework. While each of these would be discussed in detail later, their definitions are clarified in this section. The *concept* of environmental risk management is often used interchangeably with that of risk assessment [23]. In this study, risk management is the process of identifying, evaluating, selecting, and using the information from risk analysis necessary for actions to reduce risk, to human health and to ecosystems [24]. Put other way, the entire system of identifying, analysing and reducing the risks is known as the management of risk. Within precinct of management of risk, the analysis of risk is the process of hazard and exposure assessment, risk characterization. The *method* of this framework is the operational procedure of how different actions would be carried out in the framework. Use of suitable *technology* is central to the risk assessment not only for the quality of the study but also for availability and degree of ease in application, keeping in view the limited time that would be allocated for the strictly technical parts of the framework. The *cultural change* is the concerted changes needed to ensure that the findings of the risk assessment are integrated appropriately in the operations of the company.

## 2.2. The position of the proposed environmental management framework in the current managerial practice

As all Veidekke working units follow the ISO 9001 standard and its environmental management division is based on ISO 14001 guidelines, the framework is designed to be incorporated in the Deming Cycle structure that is evident in both the general management and environmental management. The point of departure here was to recognise that there would be certain similarities in the operations of the environmental management and the general management divisions. This was all the more obvious as continual improvement, a hallmark of both ISO 9000 and ISO 14001 are enshrined in the operations of the company, as Veidekke is ISO 9000 certified and the environmental management system followed the ISO 14001. As both of these codes aim at ensuring quality which is one of the most keenly and persistently pursued characteristics, a linking of the framework through the quality standards is considered to be the best option for integration [25].



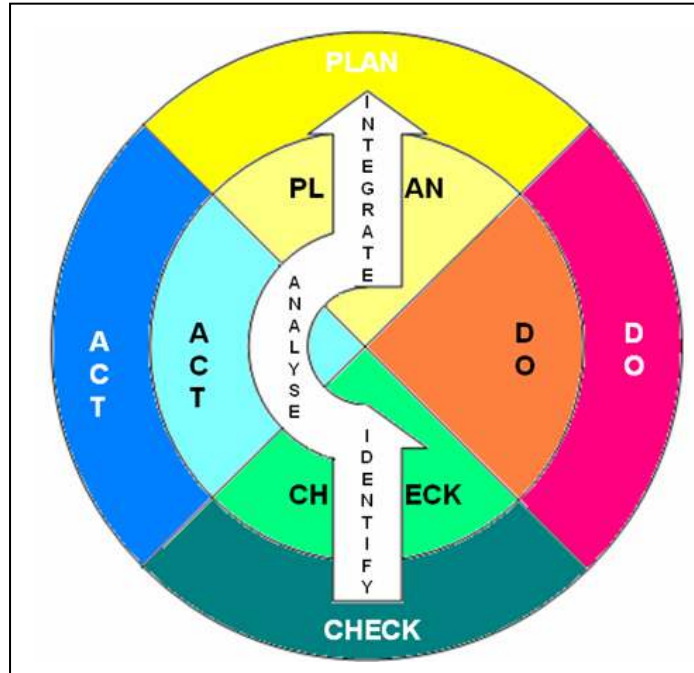


Figure 5: *Position of the framework in general and environmental management*

Fig. 5 shows how the framework is designed into the environmental and general management of Veidekke.

The outer circle represents the actions of the general management while the inner one does so for environmental management. The three basic components of the framework are described in the background of the two management cycles. The circles represent the Plan-Do-Check-Act cycle, more commonly known as the Deming Cycle [26]. The Deming Cycle is a common quality assurance tool between ISO 9001 and ISO 14001 [27]. It is assumed here that the phases of the Deming Cycle are synchronised between the two management levels. This can be assumed to be true for most of the time, although sporadic minor epochs between them cannot be ruled out [5]. The first process of the framework – Identification would start at the general business level. This was designed with a view to the fact that the stakeholder inputs that can be presumed to be an important source for identification of environmental risk are currently done for non-environmental concerns. Thus introducing an environmental identification through the stakeholder interaction would actually be an augmentation of the current process. Thus the Identification phase has its roots from the Check stage of general management, where it is expected that the general management would do a comprehensive review of the concerns its facing including those from environmental concerns. As stakeholder concerns are one of the primary reasons why this framework was conceived, it is kept as the starting point of the first process of the framework. The latter stages of the framework can be presumed to need refining from the environmental management. This is based on the assumption that due to the varied knowledge level in the stakeholders may actually produce a range of environmental issues to be probed that are not readily usable in the technology used for the Analysis phase. Thus the Identification phase is grounded at the general management level and leads into the Analysis phase at the environmental management level. The next process – Analysis is going to be entirely ensconced in the Act phase of environmental management. At this stage, the environmental concerns are to

be evaluated for their threats and as the data from the review stage is taken for assessment, this is in the Act phase of the environmental management. The nature of environmental assessment is often complex and includes several contended values in the socio-cultural settings that are used as references in the assessments. In the current setting however, the assessments, both technical and non-technical, will not aspire for pressing accuracy and thus can be done in the environmental management level itself. The last component of the framework –Integration, is based at the environmental management level where it is expected to utilise knowledge of the assessments in introducing a change in the way of working to improve the environmental risk, through better planning. These changes can be foreseen to manifest themselves in choice or refusal of certain types of construction materials or processes. For true difference in the functioning of the company though, an ad-hoc choice of materials and processes at the downstream level of environmental management is insufficient. Upstream integration of risk related information in business planning is considered as an important step towards proactive management [28]. Learning from the assessments and the implementations of the revised actions at the environmental management level, the general management will need to endorse certain decision patterns that would ensure that the operations of the organisation are as prohibitive as possible right at the environmental policy level. Thus the changes in the planning process have an endpoint in the planning phase of general management.

### **3. Delimitation**

Despite aiming to be a broad framework, certain delimitations have been followed from what would be considered part of a routine risk reduction framework. First and foremost, this framework does not foray into implementation of risk reduction actions, but leaves the scene at a level where the risk information has been integrated in the decision-making process. Due to the extreme variation in scenarios that may be needed to be dealt with for end of line implementation, this was kept beyond the scope of the work.

The framework in its current form would probably ask more questions than what it can answer. Probably the most critical delimitation of the framework is in the Analysis component, where the methods suggested are primarily to address short term environmental concerns, although the Identification component is designed to throw light even on strategic concerns. This however, is consistent with Veidekke's motivation to be aware of the risks it poses and faces even if a solution cannot be worked out at the instant. The knowledge of those issues can be of critical importance in strategic manoeuvring of the organisation [9].

More objectively, the other delimitations are as follows:

- Out of the four principles of sustainability described in § 1.1 (Part I), only the biophysical and technical ones are focussed here, because in its profile as a construction contractor those are the only principles Veidekke can influence directly
- Only construction phase environmental risks are considered
- Direct impacts are considered (indirect impacts, e.g., impacts from the manufacture of the construction material are not taken into account).

## 4. Review of existing risk management frameworks

A detailed literature review revealed a few different methods commonly used in ecological risk management [28]. The contrast in the different frameworks is largely in the different steps involved in the processes.

### 4.1. AS/NZS 4360

This particular framework encompasses all the generally accepted forms for risk – financial, meteorological as well as environmental. The steps involved here are:

*Establish the Context:* The establishment of the context refers to framing the background, which gave rise to the need for the analysis. This is for the initial scoping of the problem.

*Identify the risks:* This is a method to screen for the potentially important risks stemming from the general pool of risks. The identified risks are further analysed for their gravity and importance towards the overall process from which these risks emerge.

*Analyse the risks:* The analysis of risks leads to the genesis of the risk as well as possible scenarios arising out of the risk. The assumptions and presumptions from the risk are guided by the boundary conditions of the whole risk assessment process.

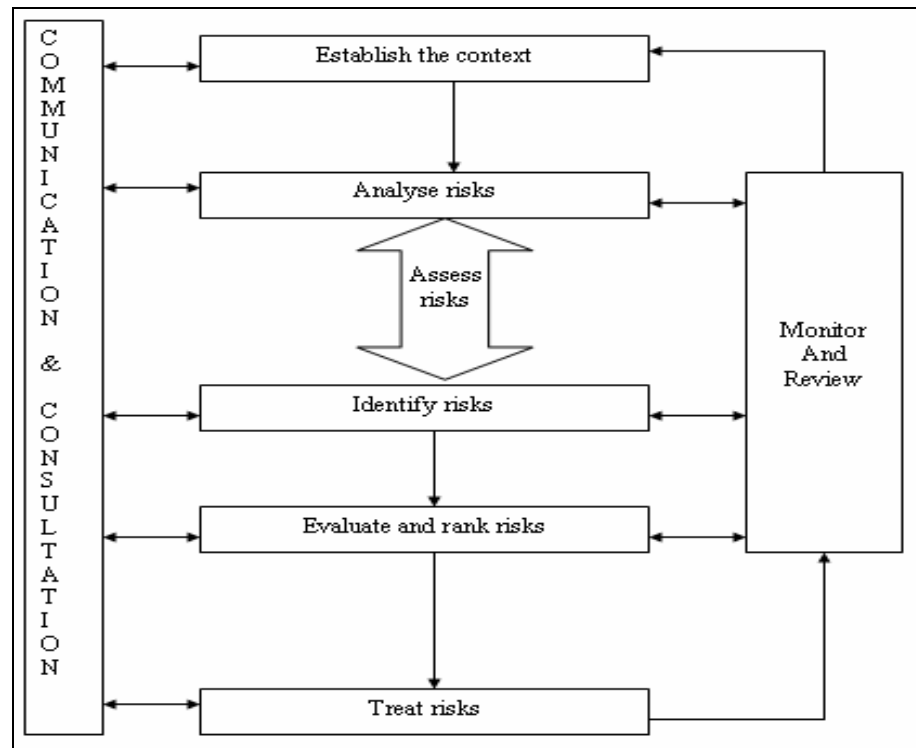


Figure 6. Risk Management Paradigm according to Australian/New Zealand Standard for Risk Management (AS/NZ 4360)

*Evaluation of risks:* Analysed risks are evaluated in preferably quantitative or otherwise in qualitative ways. Several standards in the Australian environmental protection legislations can be used as pointers in this stage as yardsticks for the risk evaluation.

*Treat Risks:* Treatment of the risks is the process when a mitigation or countering strategy has been worked out to deal with the risk. Often there is a monitoring phase in the treatment process that is either the part of this stage or is followed up on separately.

Two overarching components of the process are the self-explanatory steps - consultation and communication together with monitoring and review.

**Advantage:** This method of dealing with risks has been found fairly successful as it can be easily moulded to specific needs.

**Disadvantage:** There are a few concerns related to communication and consultation. First, there has been no clear distinction provided between the two actions – consultation and communication. It has been generally assumed that communication is a one-way process, whereas consultation has a feedback loop as well. The second issue is with the acknowledgement of the utility of the two processes – consultation and communication. The defence sector, one of the earliest users of this framework was not too taken by the idea of risk management being better with public involvement into their activities.

#### 4.2. Beer – Ziolkowski framework

The AS/NZS 4360 being a generic framework throws up quite a few different challenges when applied to environmental applications for lack of normative guidance. In the Supervising Scientists Report 102:1995, Beer and Ziolkowski modified the AS/NZS 4360 to account for more hazard analysis, on the lines of those in Environmental Impact Assessment (EIA). EIA includes a cause and concern analysis and such studies if included in the risk assessment make for a hazard analysis step as well.

*Identify, Analyse, Evaluate* and *Treat* are the main action of this framework too, as in AS/NZS 4360. However, to enable a better understanding of the actions, they are further broken down in the Beer-Ziolkowski framework, to sub-actions, as shown in the outer circle. The sub-action under *Identify* is a measure of concern and consequence of the risks. The *Analysis* component arrives at risk analysis for the chosen system by calculating the consequences with uncertainty analysis. *Evaluation* is a process of comparing the analysis results with some external values. *Treatment* on the other hand, is the process of implementing control measures and communicating the process of risk management to parties with vested interest in the exercise.

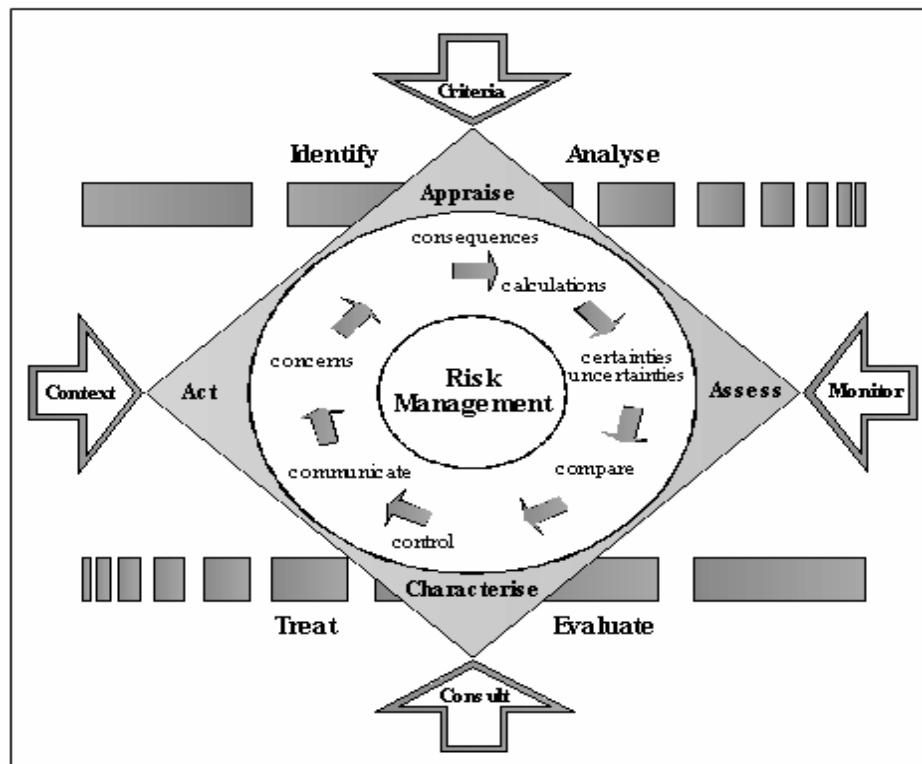


Figure 7. Beer-Ziolkowski framework

Figure 7 shows the whole practice of the risk management framework.

Apart from breaking down actions into more accomplishable sub-actions, this framework draws up four overarching goals unlike two such ones in AS 4360. These are –

- *Context* of the exercise
- *Criteria* setting against which subsequent evaluation will take place
- *Checking* in the form of monitoring and review
- *Consultation* with parties with vested interest

Overarching goals in principle are a great aid when the task at hand is complicated and has overlapping steps.

Further, the actions are also suggested to be interlinked, as in Identify with Analyse and Evaluate with Treat. This interlinking allows for a more logical and comprehensive course of action.

The Beer-Ziolkowski framework is considered to be a competent and integrated approach suitable for large scale operations.

**Advantages:** This is considered to be one of the more evolved types of frameworks as it builds upon an existing risk framework rather than proposing something entirely new. Moreover, this is also one of the most comprehensive ones, taking onboard not only the factors identification, analysis, treatment and evaluation but also looks into the interplay amongst them.

**Disadvantage:** Can become complicated to interpret in large organisational applications.

### 4.3. National Research Council Framework

This framework is by far the most popular one in the US and is recommended by the US Environmental Protection Agency (USEPA). This is also one of the very few ones wherein the approach is not integrated – risk management and risk assessment are treated as independent components in the risk-handling scenario. The basis for this is the perspective that separates the risk management as one with socio-economic implications and risk assessment as one with strictly quantitative and natural science oriented methods. According to the proponents of this school, this method originated in response to the difficulties faced by earlier generations of engineers and planners in extracting the objectivity from the overwhelmingly subjective decision about risk management.

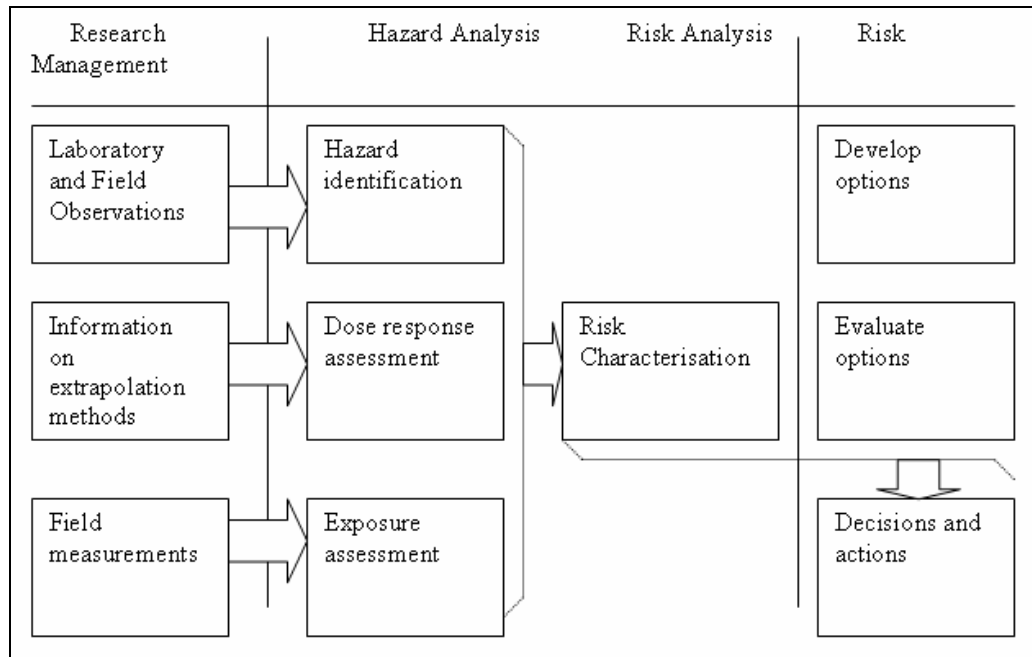


Figure 8. *National Research Council Framework*

This method has been found suitable for the organisations that consider themselves composed of “technicians and regulators”, i.e. where the management functions are clearly treated distinctly from the managerial operations.

This framework too is not without its fallacies. Careful and systematic descriptions of relevant project aspects remain outside the immediate scope of work. Particularly, delineation of boundaries in time and space are contentious issues in this type of framework.

**Advantage:** Acknowledged as a simple yet well rounded method of analysing risk. This is also suited for situations requiring tiered risk assessment – the assessment of risk and the socio-economic aspects of managing the risk are at different levels of control.

**Disadvantage:** Treating risk assessment and management as distinct stages go as the biggest drawback of this system. While the recent focus in academia has been to integrate risk related concerns into one whole, such division of work does not hold the prospect of wide application. The Asian Development Bank deems this fit for only a select few cases where there is decentralised decision-making.

#### 4.4. Modified Congressional Commission on Risk Assessment and Risk Management Framework

Faced with a rather overbearing criticism for treating the management and assessment in a complimentary yet detached manner, there was an updated framework that came from the Congressional Commission on Risk Assessment and Risk Management Framework in 1997.

This framework had the main accent on the stakeholder participation.

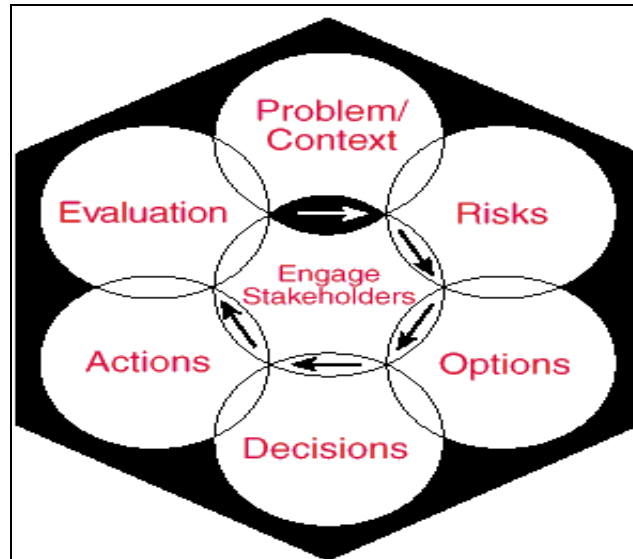


Figure 9. *Modified Congressional Commission on Risk Assessment and Risk Management Framework*

This approach has a fundamental point of relevance in this study as in this study too is collaboration and iteration. Moreover, quite like the representation in this model, the interaction is at multiple stages involving different tasks.

**Advantage:** This framework keeps the consultation as the overarching principle in the entire risk management framework. Additionally, it revises upon its previous version in integrating the risk analysis and decision-making.

**Disadvantage:** Although there is a clear emphasis on stakeholders, there is no structure suggested as to how the risk management should actually be carried out. While this can be interpreted as an opportunity to modulate the system to need, there is also a greater risk of lack of direction in this method.

### 5. Choice of framework for the project

Veidekke aspires to develop further along ISO 14001 guidelines in future. Out of the studied frameworks, only the Beer-Ziolkowski framework is observed to possess explicit reference to stages that correspond to the plan-do-check-act routine of the Deming Cycle of ISO 14001.

Context, Criteria, Check and Consult are the concepts in the Beer-Ziolkowski framework that act as overarching guidelines.

Secondly, the framework also acknowledges the importance of the inter-relation between the different risk assessment stages.

Furthermore, Identification, Analysis, Evaluation and Treatment are the steps of the standard that strike a chord with Hazard Identification, Analysis of Options, Risk Estimation and Risk Tolerability Decisions of the CCPS guidance which is used to build the conceptual role of the framework in BRP (Fig. 1). The actual framework for this study would not go to the extent of prescribing corrective environmental actions at site level (i.e., treatment) but serve only as a decision support to indicate that a corrective action maybe necessary. Thus the action - Treatment of the Beer-Ziolkowski (BZ) framework is not necessary here.

### 5.1. Characteristics and scope of the of the proposed framework

The proposed model is going to be built on the BZ framework characteristics.

The scope of the study will be bound by what a construction company needs to have in place for a comprehensive management of the environmental risks that can be caused by ways in which the firm may cause damage to the environment.

Fig.10 shows the three main operational components described in § 4 - *Identification*, *Analysis* and *Integration*.

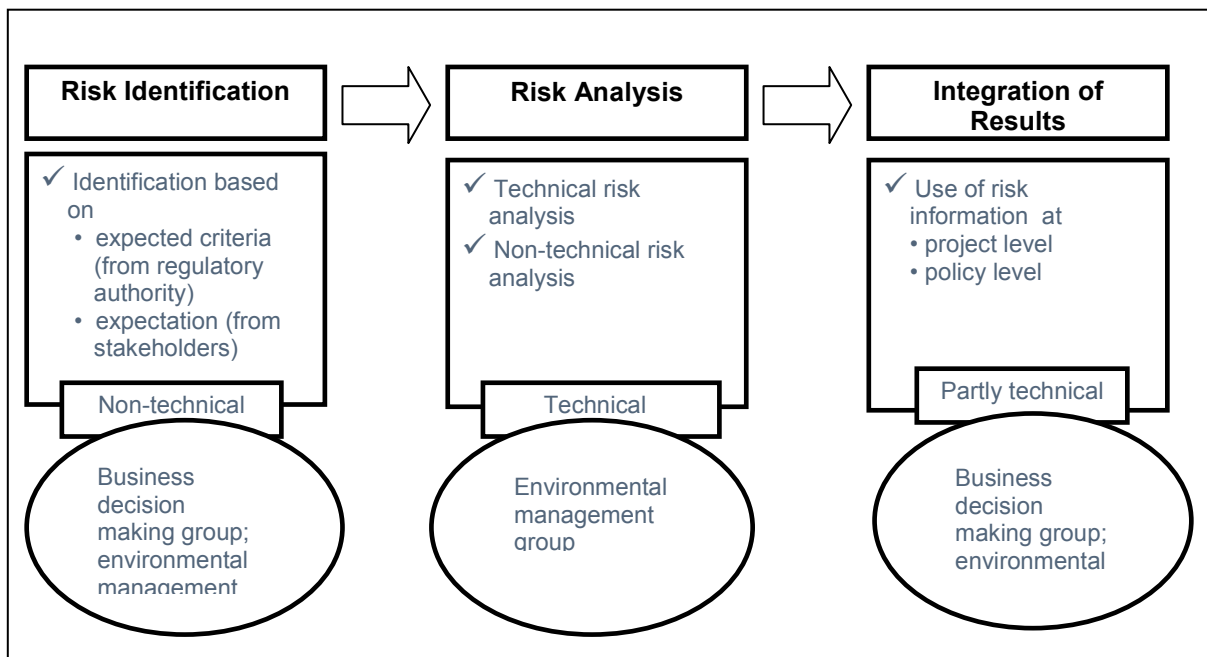


Figure 10. Main operational components of the proposed framework

The actions under each of the operational components are the objective actions of the framework, and their sequence in the framework is described in § 6, Part I. Fig. 10 also shows the nature of the objective actions and the groups involved with carrying out the actions.

### 5.2. Operational components of the proposed framework

The framework consists of three operational components - *Identification*, *Analysis*, and *Integration* as mentioned in the § 4. This section of the study presents the question these



blocks aim to answer followed by the review of literature, current practice and selection of method(s) for constructing these operational components.

### 5.2.1. Component I: Environmental Risk Identification

- What is an environmental risk for a construction company?
- What kind of data may be necessary to collect for addressing an environmental risk?
- Where and how to look for the data? (depending on the type of risk identified; in general stakeholder participation, technical guidelines, other companies' raw material usage data)

According to guidelines of the Norwegian general risk management handbook NS 5815 Section 4.5 [30], and Centre for Chemical Process Safety (CCPS), the beginning of risk management is to do a comprehensive screening of what is perceived as risk and what is not. The identification and subsequent evaluation of risk is usually done according to one of several international standards.

#### 5.2.1.1. Review of international standards for identification of environmental risks

##### *Swedish Standard SE EN ISO 14001*

The most widely used standard for environmental management in the world stipulates that the environmental aspect evaluation should cover both normal and emergency situation incidents. The identification is to be carried out in four stages - *Selection of an activity/process; Identification of the environmental aspects from the activity or process; Identification of the environmental impacts from the aspects; Appraisal of the environmental aspects.*

An example of the stages is provided in Table 4 (ref: SS EN ISO 14001) [31].

Table 4: Example of relationship between activity, aspect and impact from ISO 14001

<b>Activity or Process or Service</b>	<b>Aspect</b>	<b>Impact</b>
Activity – managing of harmful substances	Risk for spillage	Degradation of soil or water pollution
Process – product improvement	Redesign of the product	Reduced impact on the environment
Service – Maintenance of vehicles	Exhaust gas emission	Reduced air pollution

The areas of compulsory coverage are: Discharge to water; Emission to air, Waste management; Land degradation; Usage of raw material and natural resources; Other local environmental impacts.

##### *Eco Management Audit Scheme (EMAS)*

EMAS is an EU regulation linked to the framework of the 5<sup>th</sup> EU program for the environment, titled – Towards A Sustainable Development. Like the ISO 14001 this too

is non-binding. This regulation aims at putting together measures for preventing and reducing avoidable pollution, as much as possible at the source.

The areas of compulsory coverage are: Controllable and uncontrollable material discharge to atmosphere; Controllable and uncontrollable discharge to water or sewage disposal system; Routine and other types of waste generation with added attention to hazardous waste; Land degradation; Use and consumption of land, water, fuel, energy and other natural resources; Generation of noise, odour, vibration in the context of municipal or national limits. In June 1997, the EC acknowledged ISO 14001 as a standard within EMAS, in order to avoid two parallel certification systems.

EMAS has been found to be more end of line technology oriented and in general more exhaustive than ISO 14001 [32].

#### **5.2.1.2. Current method of identification of environmental risk in Veidekke**

Veidekke Entreprenør AS is not certified by ISO 14001 (except for the recycling division), but it follows ISO 14001 principles for its environmental risk identification routine. This preference of ISO 14001 to EMAS is reflected from the following factors - it is likely that if Veidekke decides to certify for ISO 14001 which is based upon the presumption that the more popular of the two EMS systems is ISO 14001, it will help in the process of certification.

The planning and execution of the risk identification and analysis follows after the four stage approach of ISO 14001 and the quality assurance of the process is after NS 5814:1991.

Environmental risk analysis and management is delegated to line managers at site, where the projects reflect the principles of the firm's environmental policy. Prior to the start of work at each of the sites, the project management team assembles a working guideline from the central database of operational regulations (Styringsystemet Kap. B14, ref. Appendix A. Environmental Impact Evaluation Proforma). This includes Terms of Reference for the environmental guideline specific to the project. There is a list of 19 undesirable incidents (Uønsket hendelse) whose impact (Konsekvens) and probability (Sannsynlighet) are ranked from 1-3, with an increasing order of magnitude. The decision to proceed with the project depends on the identified potential environmental risks which is the sum of the products of probability of occurrence and their impact of incidents. Operational regulations (Styringssystemet) recommends estimating risks according to the four stages of ISO 14001 (ref. § 5.2.1.1, Part I) standard and for the last stage it follows the common industry practice of assigning the greatest risk the highest value on the scale, i.e., 3 and the lesser consequences are grouped either as 2 or as 1.

This method has been successful and considered easy to operate in the company.

However, according to ISO 14001, the primary index for risk identification should be an activity or process or service. In case of Veidekke, the 19 undesirable incidents are mixed up between activity (e.g., stor avfallsgenerering) and impact (e.g., vegetasjon skades). Secondly, the list of undesirable incidents is based on the seven compulsory areas as stated by ISO 14001 but no explicit consideration was given to the additional six strategic areas given by the Ministry of Local Government and Regional Development, under the publication – “Environmental Action Plan for the Housing and Construction Sector 2005” [33]. These areas are – *Spatial efficiency; biodiversity; energy consumption in building stock; improved documentation; reduction of hazardous substances in construction; construction waste and recycling; quality of building design; environmentally sound building management.*

Thirdly, there is no stakeholder involvement for environmental risk identification in the start up phase. The input of stakeholders about environmental performance was found to be introduced only in the build up phase of the constructions and is well structured from there on.

Based on the above observations, main suggestions for the identification of environmental risks are:

- Increase the scope of the environmental aspects needing attention for identification by including appropriate measures from the six strategic areas
- Involving the stakeholders at the start up phase

The strategic visions have been prepared with long term sustainability views. Thus if any of the actions of Veidekke conflict with those visions, it needs to be checked. Also in tune with the effort to increase inclusiveness of environmental aspects, the identification will also need to come from various sources and participants right at the start up phase as substantial stakeholder concerns in a latter stage may require corrective measures causing large expenditure.

#### ***5.2.1.3. Suggested method for environmental risk identification***

As the operation of the environmental risk identification is well functional and does not pose any pressing needs for a complete overhaul, only a rearrangement of the current process is suggested that will integrate the improvement suggestions. The concept behind this method is to use the expected criteria from legislation and performance expectation from the stakeholders as the two agents to identify risks.

- **Identification of environmental aspects based on expected criteria**

This is to be done by analysing trends in the temporal data regarding environmental requirements or legislation. The three stages in which it is to be done are – scoping, screening and analysing (quantitatively or qualitatively).

- **Identification of environmental aspects based on expectation**

Stakeholder deliberation as a process can help Veidekke understand the risks that may need to be studied in detail. A stakeholder centred risk identification is a concept that has been used in risk identification for large projects, particularly trans-boundary environmental issues and in case of micro-economic entities, this method can be assumed to be fairly potential [34].

#### ***5.2.1.4. Working method of Identification***

- **Stage 1 (Identification of environmental aspects based on expected criteria):**

The environmental management division studies the ISO 14001 and ODIN guidelines to do trend analysis of environmental risks for a particular project.

##### ***Trend Analysis***

Trend analyses of temporal data have been long used in natural sciences for prospective studies. Building on retrospective data, these statistical operations help to ideate the future scenarios.

TA is divided into three parts – scoping, screening and analysis.

*Scoping* - In this stage the various different sources prescribing good practices are studied and an indicative study is made to relate the relevance of their applicability for Veidekke.

To start off, the base set information (ref. Appendix B. Trend Analysis) in this study is the *Environmental Action Plan for the Housing and Construction Sector 2005-2008* (EAP2005-2008), given by Norwegian Ministry of Local Government and Regional Development (Norges Kommunal- og Regional Departementet), Norway, as it's the most agreed upon and widely accepted standard in the building construction industry in Norway.

As the criteria from ISO 14001 are already in use in the identification with checklist method, this study will focus only on ODIN.

*Screening* - This part of the TA looks into the relative importance from the point of view of a construction contractor and the feasibility to carry out a trend analysis given the limitation of data. Often a distinction is made between if there is a qualitative or a quantitative study is possible.

*Analysing* - In the final step of the TA, the findings from the previous step are numerically and subjectively analysed to understand their pattern of development for at least the last 10 years or less for data constraints.

For qualitative analysis the objective is only to gain an insight into the direction to which the aspect is developing.

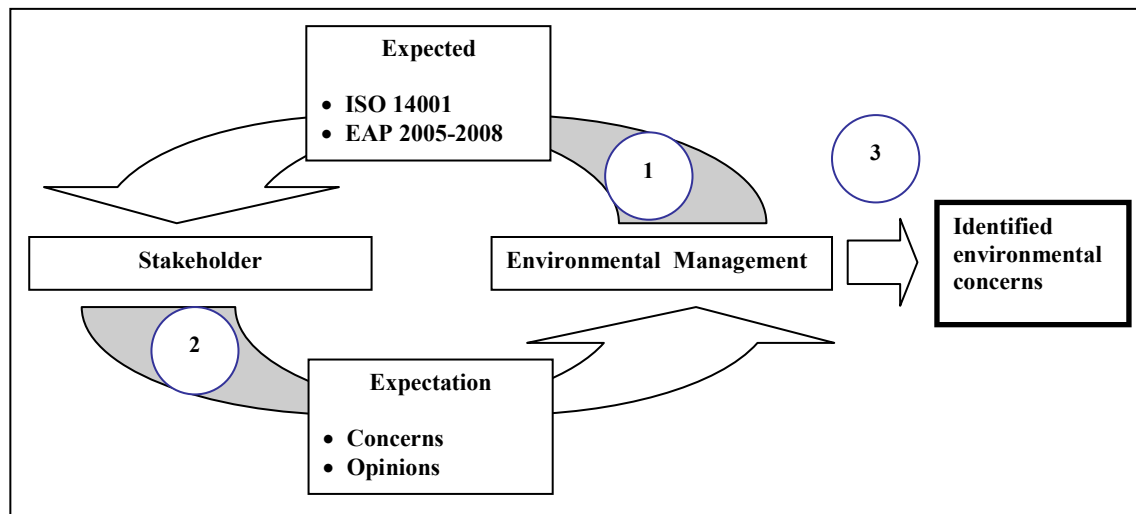


Figure 11. *Environmental Risk Identification*

• **Stage 2 (Identification of environmental aspects based on expectation):**

In this stage the stakeholders are presented the questionnaire from the previous stage and are asked to rank the environmental risks from different activities or processes proposed in the work plan in the project in the environmental backdrop (ref. Table 6).

***Stakeholder deliberation***

Before a discussion on the utility of this step, it's important to know who are referred to as the stakeholders in this context. As this study is focussed on the environmental aspects, such a perspective would yield a definition of stakeholders as: any organization, governmental entity, or individual that has a stake in or may be impacted by a given approach to environmental regulation, pollution prevention, energy conservation, etc. [35]. The extent to which different stakeholders may or can influence a company's operational decisions depends on the company's ownership and the strategic vision of the

company. In Veidekke, stakeholder engagements are substantial and thus can be expected to play an active and crucial role in the overall functioning of the company.

**Stage 3 (Initiation of risk analysis):** In this stage the environmental management division receives a list of areas that the stakeholders have contemplated and ranked according to their perceived level of importance (ref. § 1.1, Part II).

### 5.2.2. Component II: Environmental Risk Analysis

- *How to do the technical studies for managing the environmental risk?*
- *How to do the non-technical studies for managing the environmental risk?*

Risk Analysis is a combination of two factors [24]:

- The consequences of the adverse event
- The probability that an adverse event will occur.

While the consequences of an adverse effect can be judged to an appreciable level of accuracy with modern techniques, the probability function is dependent on statistical data. However, in the case of a lack of scenario or data, educated and experienced assumptions are often allowed [36].

The importance of risk assessment and analysis is well articulated in the requirements of a competent environmental risk management system [37]. In Section 4.2 of ISO 14004, several questions that underline the consideration of environmental analysis in business planning are stated. Three of them refer directly to environmental assessment and analysis:

- How frequently will a situation arise that could lead to the impact?
- What are the significant environmental aspects, considering impacts, likelihood, severity and frequency?
- Are the significant environmental impacts local, regional or global in scope?

While the need for environmental information is generally on the rise, quantified information for environmental impact from micro-level organisations is a relatively new trend. Quantification of risk assessment and analysis information would enable objective comparison between different options that can help avoid a more risky option. Whilst there have been numerous efforts to find agreeable risk analysis methods for high risk industries, such as petrochemical, nuclear and oil and gas, that have comprehensive routine for logically ordered process checks, for construction process, no specific environmental risk analysis method was found in available in open source literature on available on different media or communication [38], [5]. Within the ISO series, the importance of environmental risk assessment for impact characterisation is described but how to conduct a risk assessment or analysis that will lead to characterisation is not [37].

*No formal method of environmental risk analysis or management exists currently in Veidekke.* However, a lack of formal risk assessment framework does not imply that risks in environmental facet of business impacts are not assessed. Inasmuch as it is not a revenue earning operation in a company, specific risk assessment for environmental concerns are not deemed as important as in the core operations such as finance and human resource [39]. Interaction with key personnel revealed that the organisation did not feel the need for a formal risk analysis as there was no need as such from

stakeholders or legislations. The recent concern of stakeholders did motivate the company to find ways that would show the state of art of impact from Veidekke's constructions.

With a view to encompass all the practical considerations that go into making a decision for the sake of better environmental protection, this framework proposes a methodology to analyse risk at Veidekke in two domains – *technical* and *non-technical*. In the technical domain the analyses are natural science based or engineering decision based whereas in the non-technical, economic considerations related to the technical choices considered for risk are analysed.

- **Technical risk analysis**

These are the analyses to evaluate the environmental impacts that the operations of the company will have. It is divided into two subsections, to cover for all the impacts, both site specific and non-specific activities in the company:

- *Site specific risks:* A construction process or site that may give rise to environmentally damaging incidents, specific to the location
- *Non-site specific risks:* A material whose use in construction can cause environmental damage both during and beyond the construction phase, irrespective of the location of the use

- **Non-technical Analysis**

The non-technical analyses are the supporting research for the alternatives having varying than environmental impacts. Put other way, the technical analysis of a particular material or process might reveal that the ordinary course of action is beyond acceptable risk standards. In that case, other technical alternatives will need to be developed. However, the choice of the alternative will depend not only on the technical information (i.e., the extent of environmental impact of each of the alternatives), but also on the non-technical information such as cost, technical capacity available, time to implement etc. The non-technical assessment(s) will help to make a realistic trade-off between different options of choices having varying environmental risks.

For the sake of simplicity, only economic aspects of technical alternatives created for environmental reasons are discussed in this study. The technical risk analyses of the framework are calculated for their impact on the natural environment over their complete life cycles. Consistent with that, the costs too should range over the whole life cycle of the construction, even though the monetary transaction period (the duration for payment in installation from the clients) may well be over. Put other way, the cost estimations need to account for the environmental costs beyond the business transaction period, which is what the current practice is at Veidekke. This expansion of scope of the cost estimation for the alternatives should also consider the added market value due to the improved environmental profile of the asset. This would enable addressing the business aspect of the alternatives.

It is assumed implicitly that environmental risks, if found to be within certain extents, can be managed by adopting more secure methods of work. In other words, this framework does not solicit disapproving the use of a process or a substance merely due to presence

of risk but allows the company to explore different protective measures that can be considered to safeguard the process. The extent to which such additive measures can be allowed in a construction process or material that has been found to possess certain amounts of risk is going to be decided by Veidekke and its stakeholders (ref. § 5.2.3.3). The input that the non-technical analyses need would depend on those safeguarding measures. Thus there is a clear value judgment scenario that this framework leads to, where the costs of the original processes and safeguarding measures are compared against the advantages from safeguarding. However, this framework does not advise, under any circumstance whatsoever, a grouping of original process and a safeguarding process, if the risks from the process or the material exceeds beyond internationally accepted limits.

#### **5.2.2.1 Review of technical risk analysis methods**

As mentioned in the preceding section, the approach to technical risk analysis is bifurcated into site specific and non-site specific.

- *Review of available risk analysis methodologies for site specific risks*

The nature of the risk considered here stemming from a process operation such as construction (as opposed to say manufacture), it follows directly that a process oriented risk analysis approach will be useful. Literature survey for a formal EU level directive for selection of process risk methods for construction processes revealed a lack of such suggestion.

Within the domain of industrial process operations and quantitative assessments, three general typologies are found [40] that are as follows:

- **Qualitative Techniques:** These are the most widely used group of techniques in risk analysis. They are generally used for simpler data recording such as operational characteristics of equipments as well as toxicity and flaming points of chemical used in the process. These are used generally in planning, construction, starting up, operation, and finishing stages of a project.
  - Example: Hazard and Operability Studies (HAZOP), Failure Mode Effect Analysis (FMEA), Fault Tree Analysis (FTA) and Checklists
- **Quantitative Techniques:** These draw upon both qualitative and quantitative instances of safety measures and accidents. Quantitative methods provide the numerical interpretations of risks in particular parts of the system as well as allow comparison of different options, when it comes to using resources most cost-effectively to deal with risks.
  - Example: Maximum Credible Accident Analysis (MCAA), Chemical Process Quantitative Risk Assessment (CPQRA), Hazard Analysis — HAZAN and Consequence Analysis
- **Probabilistic Techniques:** These techniques are based upon statistical correlations between different variables influencing the risk parameters in a process. Probabilistic methods have been traditionally used in complex technical systems such as – the airlines and nuclear industries. However,

- probabilistic methods such as simple variable simulation are often part of semi-quantitative risk models that are widely used in common risk management.
- Example: Probabilistic Safety Analysis (PSA) or Probabilistic Risk Analysis (PRA).

Amongst these different typologies, a common trend can be observed in their approaches to risk analysis [41]. These are as follows:

- Identification Phase: This records site variables such as - hazardous activities, products and equipment. The output from this goes into building the processes of the actual risk analysis in the latter stages.
- Evaluation phase: In this phase, a quantification of risk is done to express its importance as compared to the other risks. There are two ways to perform this stage, depending upon whether the typology is qualitative or quantitative or probabilistic—a deterministic approach and/or a probabilistic approach. The output of this stage uses the identified risks of the previous stage incident scenarios and impacts on the site or its vicinity due to a potential incident are estimated.
- Hierarchisation phase: In this stage, a ranking of the risks are done that helps prioritise the risks.

Normally, the effect of risk is always considered with respect to its probability of occurrence and this is independent of the typology chosen to study risks.

### ***Merits and demerits of different typologies***

Table 5. *Features of risk assessment typologies*

<b><i>Characteristic Type</i></b>	<b><i>Advantage</i></b>	<b><i>Disadvantage</i></b>
<b><i>Qualitative</i></b>	<ul style="list-style-type: none"> <li>- <i>easy to use</i></li> <li>- <i>requires less resources</i></li> </ul>	- <i>limited accuracy</i>
<b><i>Quantitative</i></b>	- <i>enables ranking of alternatives on a common scale</i>	- <i>data intensive</i>
<b><i>Probabilistic</i></b>	- <i>high level of detail and accuracy</i>	- <i>data intensive</i>

- *Review of available risk management methodologies for non-site specific risks*  
Non-site specific risks in this study connote all those risks whose existence is not dependent on a construction site. The most important ones for Veidekke in this category are business decisions that can lead to environmentally harmful actions, incomprehensive



environmental policies and choice of construction material [5]. In this report, only the construction materials are chosen as the non-site specific risk as this was the only objective problem that could be addressed in the scope of the study.

Some of the commonly used hazardous construction materials are - adhesives, sealers, paint stripper, asphalt, paint/lacquer, resins/epoxies, waterproofing agents, coatings, antifreeze, shellac, solvents and caulking [46]. Although no formal audit has been done in Veidekke so far regarding the amount of use of construction material that are listed on the environmentally harmful substances register in Norway [47], approximately 9-12% of the materials in use in Veidekke are on that list [5].

This step of risk assessment is primarily to understand how different materials on that list, having the same priority for removal, impact the environment. The health and safety sheets do not enumerate the negative environmental impacts from these substances, which this assessment would, enabling a prudent choice for selection of materials. It may also turn out that either one or some or all of the materials compared for their environmental impact happen to be beyond acceptable risk tolerance values. This is unlikely though, as had that been the case, the material would have probably not been allowed to be used for a commercial purpose. Thus the utility of this step of the framework is both to measure the absolute and relative impact of the construction materials in use at Veidekke.

Material based reviews of substances takes many forms covering a vast range of levels of details. These include on the spot checking of purchased materials to extensive pre-procurement checks in the laboratory. In this study only those materials that remain in the built up installations are considered.

Starting the search for a suitable decision support system for material based risk prevention at the European Union level, a system – European Union System for the Evaluation of Substances (EUSES) was found that fully conforms to the EU Council Directive EC – 793/93 on Evaluation and Control of the Risks of “Existing” Substances, also known as ESR (Existing Substances Regulation) [48]. “Existing” substances are chemical substances in use within the European Community before September 1981 and listed in the European Inventory of Existing Commercial Chemical Substances. The risk assessment carried out under Regulation 793/93, is conducted following the principles of the Regulation 1488/94 and following the detailed methodology laid down in the Technical Guidance Document on Risk Assessment for New and Existing Substances. A user friendly software EUSES v2.0.3 has been developed by the European Chemicals Bureau (ECB), Italy which aims at refined initial risk assessment of chemicals rather than comprehensive tests.

#### ***5.2.2.2 Suggestion for technical risk analysis methods***

As there is no formal process of risk analysis at Veidekke for environmental aspects, this framework has to rely entirely upon those available from literature and found appropriate with their information requirement and deliverable.

- **Selection of a risk analysis method for site specific risks**

Based on the merits and demerits of the general types of the methods, the Fault Tree Analysis (FTA) from the qualitative group of techniques is chosen. This is primarily due to the sound logical framework that it has to offer as well as due to the possibility it offers to increase the accuracy of the study with more detailed data. FTA is one of the very few

methods that have been used in the construction industry [42]. Moreover, this method can also accommodate quantitative reliability data.

FTA is a graphical technique that provides a systematic description of the combinations of possible occurrences in a system, which can result in an undesirable outcome [43]. The most serious incident in an operational setup is selected as the Top Event. A fault tree is then construed by relating the sequences of events, called Base Events which individually or in combination, could lead to the Top Event. A Base Event is an event of failure of an equipment or process in the operational setup, which can no longer be traced to any other event within the test boundary. The relations between different types of events are expressed by logical operators – AND, OR. Each combination of critical Base Events, which is those Base Events whose simultaneous occurrence can cause the Top Event to occur, is called a Minimal Cut Set (MCS).

After the fault tree has been constructed, the next steps can be designed based on the scenarios involving availability of reliability data, i.e., the data indicating the probability of a failure of a piece of equipment or malfunctioning of a part of an operation.

### **Scenario I: Reliability data available**

If reliability data of the Base Events in the MCS are available, a quantitative measure of the Top Event probability or impact can be derived.

If the probability of the Top Event is the parameter to be derived, this is done most simply by adding up the number of occurrences of each of the base events in all the MCSs. For this, a common time reference is to be chosen, such as the total project duration or 1 year according to the choice of the risk analyser. If alternative operational setups are available, the probability of the same Top Event is calculated in the similar process, this time with a set of different Base Events as the operational setup is different. The operational set up which has a lower value of the Top Event score is chosen.

The impact of a Top Event from FTA has been used when the Base Events in the MCSs can be quantified in same dimensional units (e.g., kg/day, m<sup>3</sup>/month etc) and thus can be added up numerically to represent the total measure of the Top Event. For example, if the Top Event is discharge of oil from a construction site and the Base Events are leakages of certain chemicals, the Top Event is simply a summation of the Base Events. An example of this is a research done recently in Skanska Gottlieb, USA [42].

The reliability data, such as the number of occurrence or the amounts of discharge in a range (if not available as deterministic point values) can be used in a simulation method, such as a Monte Carlo simulation to get a more realistic value of the top event impact.

### **Scenario II: Reliability data available**

In the absence of quantitative data for estimating the probability or impact of the Top Event, the MCSs are ranked according to the importance of the Base Events in each of them. The importance is qualitatively assessed and the risk analyser considers both the number of occurrence and extent of impact implicitly. There is no established method as to how this judgment is to be done, as the judgments inevitably depend upon the type of Base Events and thus is very case specific [44]. However, as a rule of thumb, the MCSs containing lesser number of Base Events are given more priority than those with multiple base events [44]. SINTEF, Norway has produced a general rule that maybe followed as a pointer, when multiple Base Events are present in a MCS [45]. According to this, the ranking of the base events in the order of decreasing risk is - Human Error, Failure of Active Equipment, and Failure of Passive Equipment. An Active Equipment is one which works dedicatedly to the system in which the Top Event originates while a Passive

Equipment is one that is related to the system but its functions are shared with at least one more system.

The FTA methodology comprises of four compulsory steps and one optional step that are as follows:

- Definition of the problem and the boundary conditions
- Construction of the fault tree
- Identification of minimal cut sets
- Qualitative analysis of the fault tree
- Quantitative analysis of the fault tree

These steps are elaborated in § 2.2., Part II.

• ***Selection of a risk analysis method for non-site specific risks***

As there was a European wide authority, i.e., ECB available in the matter of risk assessment for chemical substances and there is only one system i.e., EUSES recommended by that authority, no further search for an alternative system was undertaken.

EUSES has the following steps:

- Selection of assessment types: The assessment type refers to the protection goals to be studied and is classified into five groups
- Defaults: This section contains the defaults for the characteristics of the environmental compartments
- Substance: Substance identification and input of physico-chemical properties
- Release estimation: Release of the substance in its different uses
- Distribution: Distribution models in EUSES calculate the spatial spread of the substance in two different scales – local and regional
- Exposure: This determines the levels to which various life forms will be able to accept the exposure without any harmful effects
- Effects assessment: This step deals with the effects of the substance on environment as well as on humans both directly and indirectly through environment
- Risk Characterisation: Risk characterization refers to the final step in EUSES, where the use of the substance is found either acceptable or not based on the Risk Characterisation Ratio (RCR) values (ref. § 2.5. Part II).

**5.2.2.3. Review of non-technical risk analysis methods**

The question of whether or not a particular risk prevention measure should be chosen depends on the cost of the protection for environmental damage compared to the benefits from the improved measures. The needs of Veidekke from an economic evaluation thus set up the ground for a Cost Benefit Analysis (CBA). This is a process that systematically compares the costs incurred for a project with the benefit it fetches. Technically, a CBA abstracts the positive and negative aspects of an alternative into one number. It has been applied to environmental projects for determining the following variables [49]:

- The efficient level of protection that balances the benefits and costs of additional protection (that maybe necessary in future)
- The optimal mix of environmental features in the alternative
- The optimal size or scale of the project
- The optimal timing of when to implement the components of the management action

It is critical to form the baseline correctly that can help gauge the benefits of the different options available. Also, it is necessary that all the work be considered in the same scope so as to be as comparable as possible.

While CBA has been successfully used to compare technical choices and monetizing the benefits, monetizing environmental safety and progress in themselves are often considered controversial. However, while enumerating the implications of different choices based on environmental characteristics, not including a CBA in the study will lead to a distorted answer in the analysis [50].

Within CBA, the calculation of costs and benefits can be done in several different ways depending on the perspective of the analysis. A reductionist perspective tries to reduce the number of variables to a working minimum, whereas the life cycle perspective addresses the concerns in a more holistic and spread out manner. A strictly profit oriented approach on the contrary focuses on a period of return on investment.

#### ***5.2.2.4 Suggestion for non-technical risk analysis method***

From § 5.2.2.3, Part I, a life cycle view based financial valuation method appears as most suitable. Life cycle thinking is a concept that has worked brought with itself a tremendous paradigm shift in the field of industrial ecology and spurred the growth of several life cycle based analysis tools such as Life Cycle Assessment (LCA) and Life Cycle Costing (LCC).

In LCC the costs incurred during the whole life cycle of the product are accounted for [51]. This has a micro focus insofar as the object of analysis is one unit of a product, process and not a macro-level such as a whole region. Moreover, this is consistent with the suggestion to move away from exclusively neo-classical theories to those that can account for technological developments for better environmental protection [52]. Total Cost Accounting (TCA) is another life cycle oriented costing method embodying the benefits of LCC where the costs and benefits of an environmental investment (e.g., a construction material) are compared over the whole life span of the investment. However, unlike LCC, the costs to the environment are not calculated as externalities, rather the cost of avoiding them is “internalised” [53]. Between LCC and TCA methods, TCA is recommended by this framework as the costs in TCA are prohibitory and thus only the “real” internal costs as opposed to “constructed” external costs. TCA findings have a direct bearing on the profitability of the operation of the firm. Secondly, TCA needs a financial forecasting method, for which the NPV method is often used [62]. NPV happens to be the underlying costing principle in Veidekke, making the use of TCA a touch easier to practice.

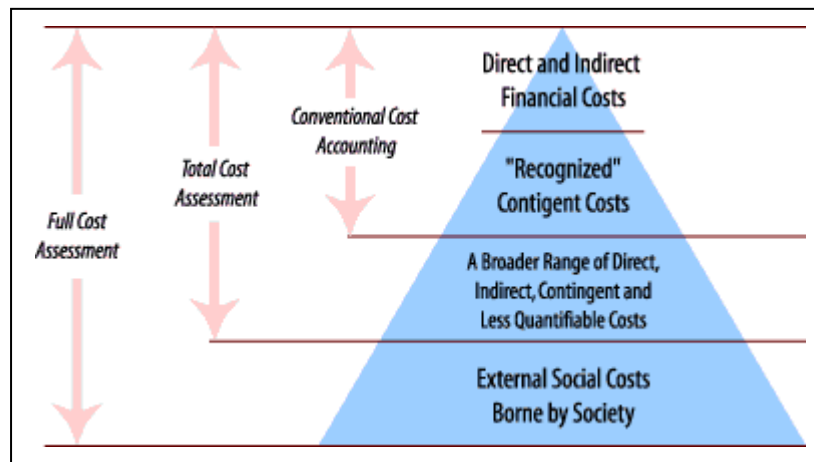


Figure 12. *Total Cost Accounting*

In essence, TCA widens the conventional steps in accounting to those that can play important costs and savings related information over the life cycle of the product being evaluated. It takes on from where conventional costing leaves and where full cost accounting methods such as LCC come in.

The steps in a TCA process are as follows:

**Stage 1: Define the decision** - Understand the options under consideration helps to identify the type of cost information needed.

**Stage 2: Identify and understand costs** – Prepare an inventory of all costs over the life cycle of the product that can have a relation to the profitability of the concern. This includes - direct costs (e.g., labour material and capital), indirect costs (e.g., cost of obtaining environmental permits), contingent costs (e.g., cost of potential violation of legal liabilities), less quantifiable costs (e.g., damage to employee morale or a negative firm perception).

**Stage 3: Analyse financial performance** – Once the inventory of costs has been assembled, do the actual financial forecasting using a discounted cash flow (DCF) such as NPV.

**Stage 4: Make the decision** – Interpret all the cost related factors that are relevant to profitability of an investment opportunity to make a choice between different project alternatives.

The last stage of TCA maybe omitted in *Analysis* as the decision to select a particular project alternative is suggested by this framework to be done in consultation with stakeholders, in § 5.2.3.3.

#### **5.2.2.5. Value additions and challenges of the usage of FTA, EUSES, and TCA methods**

The component of *Analysis* is unique to Veidekke unlike the two other components – *Identification* and *Integration*. The pros and cons of the methods suggested by the framework would thus need to be explicitly mentioned.

- **Value additions**

Apart from the general improvement in the knowledge and awareness that the framework will bring in, certain specific values can be derived from both the technical assessment models chosen here.

#### **FTA**

- The process of FTA starts with a Top Event which is an environmental incident and traces it back to the causes, unlike other qualitative methods like HAZOP. The first component of the framework, *Identification* yields indications for the likely events (i.e., Top Event) to be implored, and thus this top down method is most suited to this framework.
- Veidekke already has a functional environmental action framework which will enable a smooth transition to a more comprehensive FTA framework (several site level personnel at Veidekke are familiar with the concept of logical operator resolution methods like Job Safety Analysis process, from previous experiences in process industries)
- The current operations of Veidekke being devoid of a formal environmental risk assessment method, a knowledge and resource intensive program like quantitative or probabilistic method will be imprudent
- FTA once established as a part of the overall operations of the company can be modified to suit the specific needs the company as it supports incremental integrative application, such as probability estimation of environmental impacts on availability of reliability data

#### **EUSES**

- Improves stakeholder communication through expression of risk in internationally acknowledged risk limits
- EUSES is the only approved tool for substance based risk assessment from the European Union
- The rich base data set in EUSES avoids using subjective assumptions for often lacking data
- There is an exclusive dataset, IUCLID available for input data supply in EUSES
- The option to choose different spatial scales enables to focus the assessments to particular regions

#### **TCA**

- The principal object of analysis for Veidekke in a life cycle perspective is non-site specific risks, which translates into construction materials it uses in its buildings. Thus a product (as opposed to a service), buildings are the objects of analysis here. TCA is ideally suited to a company's products.
- Creates a comprehensive cost inventory for all internal costs of a company, by widening the scope of conventional accounting
- Can be modeled to provide indirect and less tangible costs.

- **Challenges:**

The main areas that raise question to the applicability of the suggested methods are described together with suggestive measures:

#### **FTA**

- Complicated calculation process:

The calculations in the FTA process are complicated but only if used quantitatively. For a qualitative study, the average time an experienced environmental manager of a concern like Veidekke may take is 3-4 days including site visits [5]. For quantitative studies, an array of easy to use FTA software is available in the market, thanks to the large demand of FTA.

#### **EUSES**

- Lack of knowledge for interpreting EUSES data:

EUSES allows assessing materials in several different environmental compartments on several different spatial scales. It is always possible to module the system in a way that produces the risk model only in the compartment that is considered important. Moreover, the use of base set data with suitable assessment factors is allowed by TGD of EUSES.

#### **TCA**

- TCA is not a very widely used industry practice:

TCA is one of the less complicated processes for life cycle based costing and together with the effort from the municipalities, it can be foreseen that a life cycle based costing is going to be common practice in the near future, thus removing any reservations about its lesser applicability.

### **5.2.3. Component III: Integration of environmental risk information**

- What is integration
- Why is it necessary
- What to integrate
- How to integrate

Integration is a process that aims to incorporate an idea in an already existing idea or blends in different new ideas into a composite.

The assessment and analysis of risks will produce varied type of data, which if not integrated properly in the functioning of the company will be of little use.

The types of information coming from the previous blocks that are to be taken onboard are as follows:

- Risk acceptability or reliability information for different alternatives for both site specific and non-site specific concerns
- Financial details of each of the alternatives
- Other practical considerations related to the implementation of the alternatives

As a starting point to design a channel through which the information can be utilised, the work flow of the framework is referred to. Figure 13 shows that the initiating point for the framework application can either be a routine or a circumstantial event. In the case that it's a circumstantial event, it is likely that the event would have critical importance to

the particular project where the event took place. On the contrary, a routine event would most usually point to a renewal of environmental policy renewal or something at a more planned level.

Thus the information produced can be used in two distinct levels, project and policy. This supposition is fortified also by the guidelines of ISO 14001, which says that use of environmental information should be both at the operational and policy levels [37].

- **Project level integration of risk information**

As described before, a circumstantial event is most probably specific to a project. A project demands that its issues be resolved within its life cycle. Thus the risk information from the preceding components of the framework, i.e., *Identification* and *Analysis* are to be integrated in the solution of the issue within the life cycle of the project in which the circumstantial event took place. At the project level, the risk information is part of a well defined set of information that is similar in nature as in it has specific relevance to Veidekke (the particular project), it has similar spatial characteristics (they come from a common project site), and possesses similar temporal requirements (they need to be analysed and supplied to the project control within the project duration).

- **Policy level integration of risk information**

Policy level use of risk information is more likely when there is a routine event such as environmental policy revision that required the framework initiation. Compared to project level use of risk information, the policy level use of risk information is more complex. Environmental policies at Veidekke are reviewed every 3 years [5], and thus a number of different environmental risks would need to be identified and worked through. The information required for strategic decision-making would require extensive coordination with finance, human resource and marketing divisions in a firm. As mentioned in the delimitations of this study, this framework only identifies strategic risk areas but does not analyse them. Thus there is no specific risk information meant only for policy level decision-making from this framework. The routine level initiation would mean to accumulate a number of similar short term concerns from different projects that the environmental management division would consider to have significant probability to occur in future projects as well. The information about risks that have a high probability of occurrence in the future would then be used to shape the environmental policy such that such processes or materials are avoided or used as restrictively as possible. The period of occurrence of construction processes or materials that gave rise to those concerns would be same as the period of validity of the next environmental policy.

### **5.2.3.1 Review of methods for integration of environmental risk information**

Putting together technical and non technical information for decision-making is one of the most challenging tasks a company faces. Inevitably, there is some process of synthesising the information all along a business process but often optimised performance from the use of information comes only when there is a systematic method of integrating various types of data into business decision-making [54].

*Project level integration:* At the project level, the need for integrating different types of risk information is to enable the selection of the most viable alternative amongst a set of alternatives under uncertainty. The tolerability and acceptance of risk level varies from



one project to another, depending upon the location, type of the project with potential additional requirements from the clients [5]. Thus finding a generic method to use risk information follow at project level is challenging but nonetheless extremely necessary.

The choice of accepting or not accepting the risks can be facilitated by the definition and use of a range of risks classified according to different levels of acceptance [54]. Such range based risk acceptability is promulgated by the Health and Safety Executive (HSE), UK, where the most desirable risk level is “As Low As Reasonably Practicable” (ALARP). This is quite similar to the most obvious intuitive risk management, i.e., choosing alternatives and designing operational setups with a CBA tools to understand the viability of safety measures as against the risks.

The preceding component of the framework will have yielded information about risk values (as in RCR values and probability/impact of Top Event) that can be used as the boundaries between different risk categories. Thus a categorisation and subsequent risk reduction program such as ALARP would be most suited to the framework for enabling a complete utility of the information produced.

#### *Policy level integration*

As described in § 5.2.3, Part I, designing the policy level use of environmental information is beyond the scope of this framework. Nevertheless, as the principles of the framework commit a definite value to the organisation (ref. § 2.1, Part I), it is important to see to it that sufficient wherewithal is provided for a proactive approach like using this framework is available. There is plenty of literature about good practice in EMS and propagating innovative methods in environmental management in an organisational context, a few of which are presented in § 5.2.3.3., Part I.

#### **5.2.3.2. Current method of using environmental risk information in Veidekke**

A process of systematic generation of alternatives due to environmental needs is not observed at Veidekke. The current practice of environmental risk identification and evaluation in Veidekke is done with a checklist method, as mentioned in § 5.2.1.2., Part I. This checklist does not provide any non-technical information about the construction process.

Thus there is no current process wherein multiple alternatives need to be evaluated nor is there diverse type of information that is produced. The weighted environmental aspects are “reviewed” by the project engineer at the appraisal stage of a project. This information is documented in the environmental management division. This data is normally not used for any guidance for future purpose. There is no process to abstract the data from various project level environmental aspects information to long term policy making.

The current method of Veidekke appears more out of regulation than of any proactive use of the data. This is only normal as there was no risk management effort in environmental domain, which usually calls for accounting historic data maintenance and intelligent use of risk information.

#### **5.2.3.3. Suggestion for integration of environmental risk information**

Based on the current rather inadequate system of use of risk information, a more comprehensive system of information use is suggested at the following levels of operation in Veidekke.

- **Project**

The advantage and appropriateness of the ALARP method make it the most obvious choice for integrating different parties and information for risk reduction at project level. Three classes of concepts are given by the HSE that are showed in Figure 13 [54].

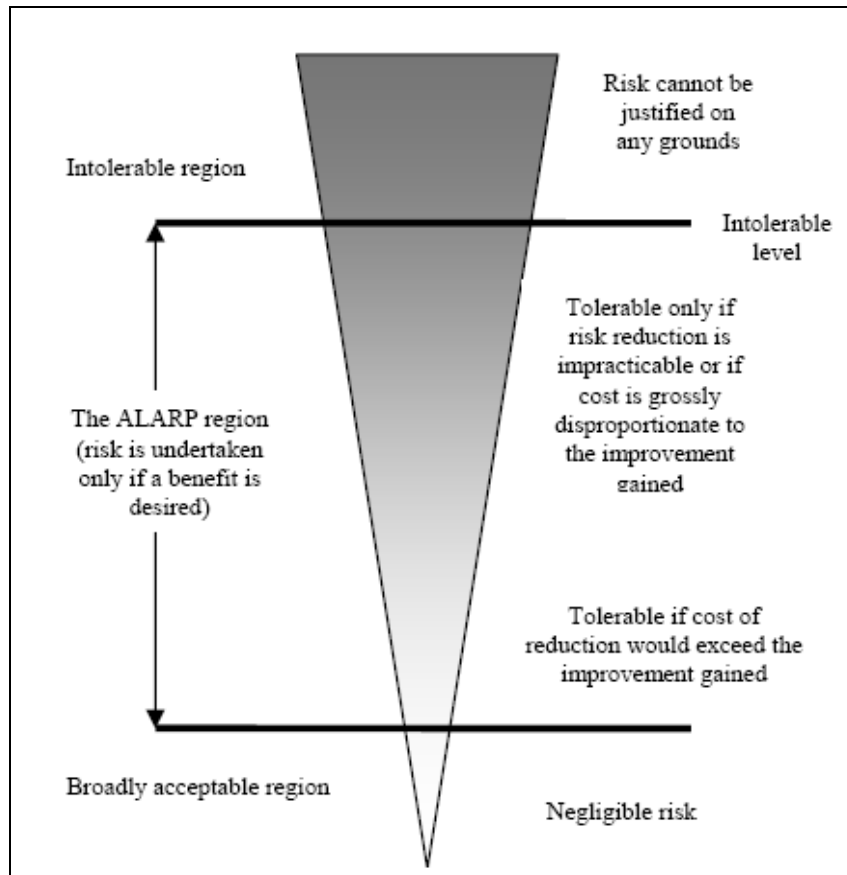


Figure 13: *Categorisation of risk levels*

In the light of this framework, these three risk categories are described as follows:

- **Intolerable:** This is the level at or above which immediate action to reduce the risk or terminate the activity is called for, irrespective of cost. For a site specific risk, this may translate into changing the operational setup such that the base events in the minimal cutsets are altered. For a non-site specific risk, this may imply discontinuing the use of the concerned construction substance.
- **Tolerable:** This level of risk, known as the ALARP region, spans from the limit where risk is considered marginally intolerable to where it is considered that control measures to reduce risk is *grossly* disproportionate to the benefits obtained. There is no normative guidance from HSE as to what factors should be taken into account in determining whether cost is grossly disproportionate [55]. Sacrifices (money, time, trouble or otherwise termed costs) and benefits (societal and firm level benefit due to reduced risk) inevitably lead to CBA as a build up towards ensuring that no further practicable risk reduction is possible. However, the HSE has further refined the range of risks where CBA might not be required and thus is more structured than intuitive risk management.

In the current context, a further specification from this framework is about the CBA. Both the costs and benefits should be prorated for the entire life cycle of the constructed property, even if that is not mandatory by law or a customary practice.

- Broadly acceptable: In this level, the benefits are proven to be grossly overshadowed by the sacrifices. Below this further reduction measures are not required.

There are three main advantages of using a structured risk categorization and reduction process as mentioned above.

First using “reasonably practicable” allows Veidekke the flexibility to decide what is “practicable” in each individual project, rather than being prescriptive which would have necessitated construction of an exhaustive number of scenarios, that would practically be beyond the scope of this study. Dwelling at the level of frameworks, this flexibility is the greatest advantage, justifying the choice of this method.

Secondly, the data requirements for this categorization and management process of risks, are compatible with the data either readily available or those that can be produced by the Analysis component of the framework, as mentioned in § 5.2.3.1., Part I. Wherever such consensual limits are not available, this framework would go on to suggest that those thresholds be set up by stakeholders, provided that those thresholds are more conservative than regulatory standards, if available. While deliberating stakeholder defined thresholds, standards or codes if available, should be used. Within the ALARP region, CBA is to be carried out which is what the non-technical risk analysis is about (ref. §. 5.2.2.4, Part I). Thus this process of project level risk reduction fully absorbs the information produced.

Finally, the HSE procedure for ascertaining that the risks are indeed in the ALARP region or lower, demonstration that the chosen option (here a construction material alternative or operational set up at site) is the lowest risk, or justification if not to stakeholders, is of utmost importance. This clear attention to stakeholders is consistent with the goal of the thesis to design the framework with stakeholder involvement as a focal objective and thus adopting the HSE procedure will ensure that this is the case.

However, certain additional steps might be required to follow this process. The *grossness of disproportion* needs to be set by each individual scenario in which the framework is used, as that will be entirely specific to the situation. In case of a disagreement between the organisation and the stakeholders, a decision aid like the Delphi method is appropriate for it is considered to be one of the simplest methods for decision-making under uncertainty [56]. Secondly, certain quantitative risk information has to be produced for setting up the risk levels between different risk categories. This has to be done, if need be, with appropriate assumptions. This is particularly likely to be done in case of site specific risk analyses, which in this study has been left at a qualitative stage.

The HSE also proposes a set of reference points that indicate if a project has reached the ALARP stage in different phases of the project. As mentioned before, the process is similar to intuitive risk management and thus the value of the HSE procedure through the framework is important to enumerate. Based on § 5.2.1, Part I and 5.2.2, Part I, this is described in Appendix C. Contribution of the framework in reducing risks to the ALARP category vis-à-vis the current EMS practice.

- **Policy**

As mentioned before, the policy level use of environmental risk information is both complex and long. Although a detailed design of policy level action to ensure is beyond the scope of this framework, certain broad policies can be suggested that will count towards ensuring that the risk information produced is used in an efficient and prudent way.

- A policy to use the risk related information from the project level as an indicator for future project selection and appraisal is proposed. This will ensure that the business is proactively seeking to avoid environmental damages learning from its previous experiences.
- The scheme for screening the information from project level for application at the policy level has to be long term, holistic and balanced with the company's business goals [57]. Put other way, the screening of information from project level to be applied, should be in line with the company's strategic visions. For example, if Veidekke decides to focus to develop its presence on a particular geographical area, the information from the project level risk assessment and analysis from previous projects should be incorporated in the decision-making of the company.
- Either a specific policy or an implicit understanding at the decision-making level should be to actively work against any negative inertia against using proactive environmental measures, such as using the framework [57]. Environmental investments have a dubious reputation of being consumers of upfront capital without guaranteed return on investment. An effort to annul such predisposition is not a direct method to integrate risk information in the policy making of Veidekke but will ensure that the process of using the framework is viewed in the right earnest, which in turn is expected to make the integration process easier.

The use of environmental risk information in policy making is a well researched issue in literature. However, most of the literature has focussed on policy making in a spatial planning context where a much higher number of control mechanisms, mainly legal and economic in nature are available. For a micro-unit such as an independent construction contractor like Veidekke, the mechanisms are fewer and thus it will depend largely on the management of the company to take the information produced, any forward. The above mentioned policies are only some of those that can be envisaged to help in this matter but there can sure be many others. Given that Veidekke already considers risks (such as financial risk) into its management planning, the concept of incorporating environmental risk information too in the planning process is not too far off the line. Top management interest being one of the drivers for this framework, using the risk information at the management planning can be clearly foreseen.

## **6. Result**

It is challenging to design a framework to suit the needs of a company already well functioning in terms of its environmental performance without getting into the tantalising world of sophisticated and precision oriented tools for want of resources and yet achieve some real value addition to the existing process. The three components having been described in § 5, Part I, the relation between them, i.e., the working method of the

framework through the objective actions can now be enumerated as the final result of all the preceding reviews and suggestive measures .

## 6.1 Objective actions of the framework

*Circumstantial event:* Any out of turn event that may trigger the framework being used. This can be the discovery of a hitherto unknown potential risk of a particular material or a process that's being used; a media exposure of an inappropriate operation in the construction industry or something unforeseen that may require an immediate addressing.  
*Corresponds to Identification (Block I).*

*Routine event:* This represents any planned event that will entitle undertaking a full scale framework application. Any prescheduled event such as the revision and upgrade of environmental routine or policy, a change in the company's operating strategy can be such type of event.  
*Corresponds to Identification (Block I).*

*Trend Analysis:* TA is undertaken as a preliminary scoping tool to understand the extent to which certain aspects should be studied. It can be either qualitative or quantitative. Either a circumstantial or routine event can initiate a trend analysis. A circumstantial event would typically be a project level concern and a routine event can be either a project level concern or a policy level concern. The data from trend analysis is supplied to Stakeholders to contemplate if there is a substantial concern that needs to be analysed or if the stakeholders have something more to add to the list of concerns prepared by the environmental management division.  
*Corresponds to Identification (Block I).*

*Stakeholder Deliberation:* This is one of the most important aspects of the risk management framework, as at this stage a list of probable issues to be studied further are shortlisted for actual study. The main objective of this step is to ensure institutional support from the stakeholders about the risk assessment activities. This will typically be a discussion session where the issues identified so far are either deemed unimportant or approved for further study. If there is a concern stakeholders would like to probe further, the next step is to analyse the problem in technical and non-technical domains. If there is no concern, the no further action is needed.  
*Corresponds to Identification (Block I).*

*Conversion of concerns into analysable parameters:* This is an intermediate step where the environmental concerns stemming from the stakeholder deliberations are converted into workable input parameters in the risk assessment frameworks. This is done by converting the concerns into something that is related particularly either to a construction process or a substance. Along with this conversion, several other variables that are required to build the system are contrived such as site conditions where a process maybe taking place or the risk scales on which the substances impacts are measured. These parameters are now ready to be used for analyses in technical and non-technical domains.  
*Corresponds to Analysis (Block II).*

*Technical Risk Analysis Information:* Technical risks analyses are studies that examine effects of the organisation's activity on ecosystem and human health. In this study the technical analyses are divided into two components – those that are for process based risks and those that are for substance based risks. Process refers to a particular type of construction method or operational setting and substance refers to a particular type of construction material. This step establishes if the risks arising out of the processes and substances are acceptable by generally acknowledged standards. Feedback is to be provided to the *Identification*.

*Corresponds to Analysis (Component II).*

*Non-technical Risk Analyses Information:* These are the support analyses to the technical analyses, such as costs associated with the change and long term impacts of the changes.

*Corresponds to Analysis (Block II).*

*Integration of results:* This step is combines different estimates to manage environmental risk. The technical and non-technical analyses of the risks, availability of alternative process or substance, decision to apply the changes at the project level or the policy level are some of the thing to be contemplated at this stage.

This is the last step of the framework. The recommendation for integration methods is kept to the level of recommendation only as there can be extremely varied scenarios and criteria to choose from since the choice of environmental fortification lies on the interface of several diverse organisational functions such as human resource, finance and marketing.

*Corresponds to Analysis (Block III).*

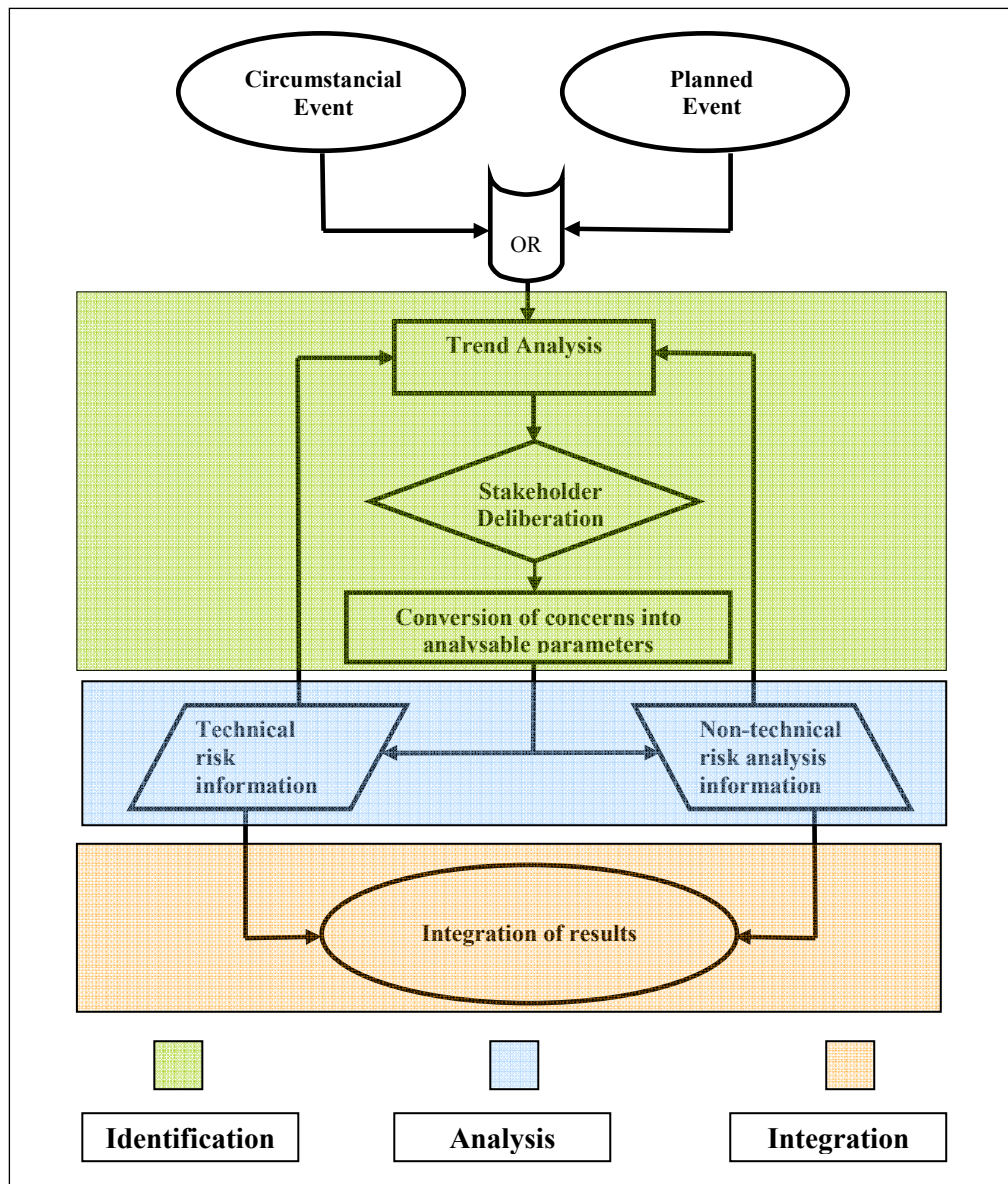


Figure 13. *The environmental risk management framework*

## 6.2 Working of the framework

The framework is initiated by a planned event such as environmental policy upgrading or a circumstantial event such as an identified environmental threat by the existing environmental management setup at the project site. The environmental management division prepares a list of those concerns together with a trend analysis of the environmental regulations. This ensures that not only the short term effects of the concerns but also the long term concerns possible from the indicators are considered. The environmental management division then supplies the stakeholders the list of concerns and ask them to add any additional concern and ranks them according to stakeholder priority.

These concerns are then grouped into material based or product based concerns and analysed. Using the EU substance risk evaluation method - European Union System for the Evaluation of Substances (EUSES), a construction material based concern analysis yields figures of risk characterization in different environmental compartments. Whether

to proceed with the material usage or not is judged by the RCR values. The choice between two materials, both of which are having RCR values less than one, will depend upon which material has a lower RCR. A process based concern analysed by the Fault Tree Analysis (FTA) method only with qualitative data would result in a group of Base Events classified according to their risk potential in terms of probability and frequency of occurrence. Selecting one process over another would thus depend upon the type of basic events and a subjective assessment of their risk potential. The extent of damage by the Top Event, sensitivity analysis of each of the Base Events and objective risk analysis can be done with quantitative data. The choice of FTA over other process based risk analysis method allows simulation methods like Monte Carlo Simulation for more reliable results. The technical analyses are judged by the costs different alternatives will incur, with a TCA perspective. Moving away from a monetary transaction based duration as the span for evaluating the costs of alternatives to a life cycle based approach is a proactive and more responsible move.

The information (technical and non-technical for selecting between different construction materials and processes) are then grafted into project level and policy level decisions. The project level use, normally when a circumstantial event initiates the framework actions, will manifest into either continuing with the regular alternative, modifying it or choosing another alternative, all within the life cycle of the same project. The project level integration of technical and non-technical data is best used by a risk categorization and management process, leading to an ALARP risk scenario. Stakeholders are involved in ensuring that the risks are indeed within the ALARP region. However, before the risk information is used for decision-making process, it is routed back to the level of *Identification*. This is to check if the alternative suggested by the risk analysis to be safe is unsafe in the context of a different foreseeable risk. This can be particularly so for site based risk analysis as a FTA method does not check for environmental endpoints but only for the occurrence of Top Event. Thus an alternative project set up that has a lesser probability of the Top Event occurrence can come across as a safer option, while at the same time posing a substantial risk for a separate Top Event incident. If it is indeed found that the alternative does have the potential for a different type of risk, the Trend Analysis step would then start to screen for environmental regulations that cover for this second type of risk and the entire framework from that stage on would have one more iteration. Such iterations would need to continue till no foreseeable risks are considered at least in the ALARP region or less in the project. Complimentary actions at the policy level encouraging the use of environmental risk information for project appraisal and promoting the use of technology to assess environmental risk are necessary.

### 6.3. Structural comparison with Beer-Ziolkowski framework

As mentioned before this model was based on the Beer-Ziolkowski framework. The main similarities are as follows:

- Criteria, context, check and consult are four overarching goals recommended to be followed explicitly in a framework in the Beer-Ziolkowski framework. The proposed framework stipulates that criteria be set from ISO 14001 and ODIN guidelines. The use of the framework also has a specific context – circumstance or routine. The context sets out as to how the information from the framework is going to be used, as in whether in project level (circumstance) or in policy level (routine). Checking is ensured by the different analysis methods, namely technical



and non-technical. Consultation is probably the most important goal in this study as stakeholder consultation (in Identification) as well as disseminating the information to the upper management (in Integration) are part of the framework.

- There are two closed loops suggested between different steps in a framework in the Beer Ziolkowski model. These are between identification & analysis and treatment & evaluation. The proposed framework does not foray into normative site level treatment guidelines at the project level. However, there is a clear feedback loop suggested from the technical and non-technical risks to the identification stage (between components II and I). Thus given the scope of its work, the framework imbibes the reversibility ideas.

## 7. Discussion

This study was carried out principally from a off site location in Stockholm, due to several practical concerns such as time and resource. However, the goal of the study being to design a very broad framework approach towards environmental risks rather than those at a specific project, this constraint did not play a very major role. Still a few options could have made this study more rounded such as using the questionnaire from trend analysis (Table 5) for identification, holding a stakeholder deliberation round in line with the methods of Component II (*Identification*) and comparing the existing project duration based costing method to that of a TCA based costing for a real alternative.

Despite the deficiencies, the framework is consistent with the process oriented principles of sustainable construction (cf. Fig. 2).

The principle of undertaking prior estimates of proposed activities is only partly exercised now as only the site based hazard potentials are taken onboard. Neither substance related risk estimates nor potential strategic risks areas are taken into consideration. The framework rounds up these deficiencies.

Timely involvement of stakeholders is better achieved by upstream consultation at the problem identification stage, which is also suggested by the framework.

The framework also uses systems ecology based testing methods for prioritizing substances and life cycle costs of alternatives, both of which are new to the organization.

The organization has never found itself in any legal complication due to environmental reasons but this is all the more fortified by suggesting a trend analysis of recent environmental regulation and inclusion of regulatory authority representation in the stakeholder deliberation right in the first stage of the framework - *Identification*.

The framework does not explicitly identify setting up targets or goals but leaves enough opportunities to the environmental management division to set those up in various different stages of its operation. For example, once the RCR values for different environmental endpoints have been calculated for commonly used construction substances, it is possible to set up thresholds, preferably stakeholder defined, for introducing new substances.

Monitoring too is an area that lacks clear application in the organization, which is what the framework would necessitate as it would yield retrospective data that are often used for quantitative analyses.

Self regulation is a process enshrined in the values of the organization and the need to create this framework adds a feather to the commitment towards progress.

It would be pertinent to discuss how the thesis measures up to its own aims, other than satisfying the principles of sustainable construction. The aim of this thesis has been to add certain values to the current environmental management practice at Veidekke. The framework has not been operational yet and thus the benefits from it present a case of testable hypothesis. Consistent with the objectives of the study, stakeholder involvement is suggested at all the stages, thereby ensuring added transparency in the process. The capacity building about risk in different levels of the organisation is also accomplished as personnel from various levels are involved in the operation of the framework activities. For example, the environmental management division, a middle management division, has to work with the upper management, e.g., the business decision-making body to communicate the plans for risk management as well as to suggest changes in the policies that can benefit from environment related information while it also needs to engage site based technical level staff to work out the risk analysis steps. As this study was initiated by the organisation itself and substantial amount of the study was the result of interaction with the environmental management staff of the organisation, acceptability of the study in the environmental management division is ensured. It is upon that division though to ensure that the mechanism to operate the framework is in place.

However, for all the advantages, there are certain question marks over the qualities of the framework, mostly related to involving stakeholders in risk management. Although the involvement of stakeholders is a hallmark of improved business ethics, several aspects of the management intention to drive a stakeholder centric environmental risk management framework may raise questions in cross-cutting divisions. For example, the choice between two different construction materials, both of which are approved for usage but are on the phase out substance list, will depend upon the relative effect of them on the environment but the management will also be interested in the non-technical details such as the costs. Is it alright to divulge cost related information to stakeholders that would inevitably have the company's own financial plans? What if the stakeholders, their position now even more centralized in the scheme of things, do not agree with the decisions of the management over the selection of a particular material or process? These are some of the questions that would need to be addressed at their respective individual level, as a broad-brush framework approach simply cannot reach down to that level of detail. This is not to discourage the use of the framework but just to make aware of the support and follow-up it would need to be successful.

## **8. Conclusion**

Environmental risk management frameworks for construction companies have not been developed due to several reasons, as described in Introduction. This study has attempted to put together one, selecting a basic structure from various recognized risk management frameworks and characterizing it with the needs of a typical construction company in Scandinavia.

First and foremost, it can be unquestionably deduced that Veidekke has an understanding of the values of risk management in environmental management system. Secondly, it also became evident that despite management aspirations of an improved environmental management through introducing a risk management perspective, there is a lack of structured process that can help the firm reach the level of protection it expects. This thesis is perhaps the only one wherein stakeholder involvement, environmental risks

analysis and integration of results in the company operations have been combined for a construction concern.

A continual challenge faced during the length of the framework was lack of real quantitative data from the projects that could be used in the risk analysis stage. This however, is held an issue only with Veidekke but construction companies in general [5]. A third conclusion therefore is, that in the absence of an comprehensive process of environmental risk management, appropriate data too is lacking that are crucial to the accuracy of the risk management process.

Finally, the study also concludes that a lack of construction phase risk assessments can lead to prolonged risks from the built environment. There is no clear method followed at the organization to choose between construction materials when all the alternatives are in the same hazard category. Although prudence is exercised in making the selection, the lack of a scientific logic, such as the actual risk potential of those materials, can be potentially a very serious shortcoming.

While the advantages and disadvantages of this particular framework remain to be tested in reality, it can be held forth that in general more empiric research should be aimed at construction stage operations of built environment. Such studies will also expose the specific data required and will develop the knowledge capacity at the firm level to address the risk concerns comprehensively. From the perspective of construction industries too, such research will do justice to their proactive commitment towards sustainability and enable them to contribute in a more assured way.

All said, it must be concluded that adoption of a risk management strategy still cannot completely preclude chances of an environmentally damaging incident, but can certainly go a long way in minimising the chances.

Taking *calculated* risks is after all not all that risky!

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## Part II: APPLICATION OF THE FRAMEWORK

In this section, case studies for the methods in components – *Identification* and *Analysis* (technical) are presented. An ideal case study would have been to focus on the running projects of Veidekke. In that way, any change suggested by this framework would have been possible to be utilised before the projects get over. Also the coherent flow of information would have illustrated the links between the different components.

This was unfortunately not possible due to time constraints. The data sources from different risk analyses, e.g., the site specific analyses and non-site specific analyses in § 2.1 and 2.2, Part II respectively, do not stem from the same source for identification of concerns in § 1.1, Part II. The identification of concern through stakeholder deliberation is sourced from a recent Corporate Social Responsibility (CSR) motivated meeting with stakeholders, whereas the issues analysed are from current projects in line with the aspiration to have a real-time value to Veidekke.

### 1. Elucidation of Component I: *Identification*

- Trend Analysis (TA) : For initial study, refer to Appendix B. Trend Analysis

Table 6. *Trend Analysis questionnaire*

Objective	Qualitative	Quantitative
1	a) Participatory aspect : - Any new regulations for areas requiring compulsory participatory aspect action by the construction contractor ? - Any new method for participatory dialogue process? b) Any need for construction contractor to do environmental assessment of the construction site, beyond the EA done at the planning stage?	NA
2	a) Energy source: What type of energy might be used for - i. energy supply in buildings (design consideration)? ii. energy supply at site for the construction process?	b) Energy quantity: What is the design energy consumption in the typical construction types for 3 periods each of 3 years duration?
3	What are the allowable types of hazardous waste?	What are allowable limits of hazardous waste?
4	Any new material coming to be recognised as waste?	Amount of waste applicable for construction process
5	NA	NA
6	Any new EMS regulation to be followed at the construction site, that	NA

	are specifically related to construction process or documentation?	
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- Stakeholder Deliberation (SD): The results below are from a recent study conducted with similar goals by the corporate social responsibility (CSR) work group at Veidekke.

### 1.1. Identified environmental concerns

The identified aspects from the October 2005 study are as follows along with the points they were assigned in order of importance attached to them.

- Environmentally hazardous materials (Miljøfarlige stoffer): 11
- Operational energy in buildings (Energi i drift opbygda miljø): 10
- Waste – inappropriate management and sorting (Avfall - uheldig avfallshåndtering og kildesortering): 3+4=7
- Harmful substance for health and environment (Helse- og miljøfarlige stoffer): 7
- Increase in energy consumption (Høyt energiforbruk i drift): 7
- Waste – bulk waste generation and inappropriate management (Avfall – stor avfallsgenerering og uheldig håndtering): 5 + 5
- Discharge to water and earth (Utslipp til vann og grunn): 5+5

## 2. Elucidation of Component II: Risk Analysis

In this step the identified risks from Block I are analysed for their technical and non-technical risks. Non-technical risk assessment will not be exemplified due to lack of data.

### 2.1 Site specific risk assessment: Identification of the hazardous process

Process based risk concerns are almost always site specific and the knowledge of common concerns of stakeholders from them builds up an inherent idea about expected reactions from the stakeholders for similar future projects [5]. Interactions with personnel at Veidekke indicated that past issues at site level operations have been dependent on two factors – internal setting of the construction (quality and reliability of machines) and external setting (geophysical condition of the site, distance to water resources and human inhabitions). Thus the example to be used here would ideally try to capture some of those elements.

#### Identification of the material to be assessed by FTA method

Project Name: Grunn- og fundamenteringsarbeider for underetasjen for felt F2, Tjuvholmen Bydel.

Project description: Foundation for plot F2 in Tjuvholmen locality. The plot is a former sea port in Inner Oslo Fjord (indre Oslofjord). Area of construction is 8500 m<sup>2</sup>. Major tasks include using water borne pile foundation, construction of a RCC parking place and waste management at site.

Location: Oslo

Client: Tjuvholmen Utvikling AS

Duration: June 2005 – April 2006  
Project cost: NOK 85 Mn. (approx.)

The environmental manager was sent a description of the FTA method and its intended application in Veidekke. Upon approval of this idea, further details were sent as to how to construct a FTA. A second person working at the Tjuvholmen site was assigned this task and further interactions with that person resulted in the FTA related studies in the thesis.

## 2.2. Performing the site specific risk assessment

Preliminary discussions revealed that quantitative analysis would be impossible given the lack of data as well as expertise at Veidekke. Thus a qualitative FTA was carried out according to the 4 stage FTA guideline of SINTEF [45]. The following section describes the different steps of the analysis.

### Step1: Definition of the problem and the boundary conditions

The project is large and complex and given Veidekke's normal routine of operations, is technically challenging. The top event is the release of oil into sea during the piling from sea borne barges. The system where this top event may occur is the process of construction of cofferdam for the waterfront embankment at Tjuvholmen, field number F2.

In this set up, only the systems that are directly related to accidental release of oil during piling process are considered. The piling process involves two main types of oils – diesel and hydraulic. Diesel is used to run the main piling assembly, as well as to supply power in the overall unit, as no usage of dry cell fuelled electricity is permitted in sea-borne construction setups. Due to the constant use of the oil, it is stored in large quantity in the construction assembly complemented with at least one feed from the land supply per day to the containers on the barge. This is regulated mostly by the project manager/engineer and is a rather simple manual operation. The primary use of hydraulic oil in the project is only in the drilling core of the trenching assembly for the piling with minor use in other transmission and braking systems. At the project site, the hydraulic oil is stored and administered by a centralized automated regulation system. Hydraulic oil used at Tjuvholmen are of two types – Durad (mineral oil) and Quintolubric (polyalphaolefin). Both of these have high boiling points and low freezing points.

### Step 2. Construction of the fault tree

Based on the boundary conditions, a fault tree was constructed, which is as follows:

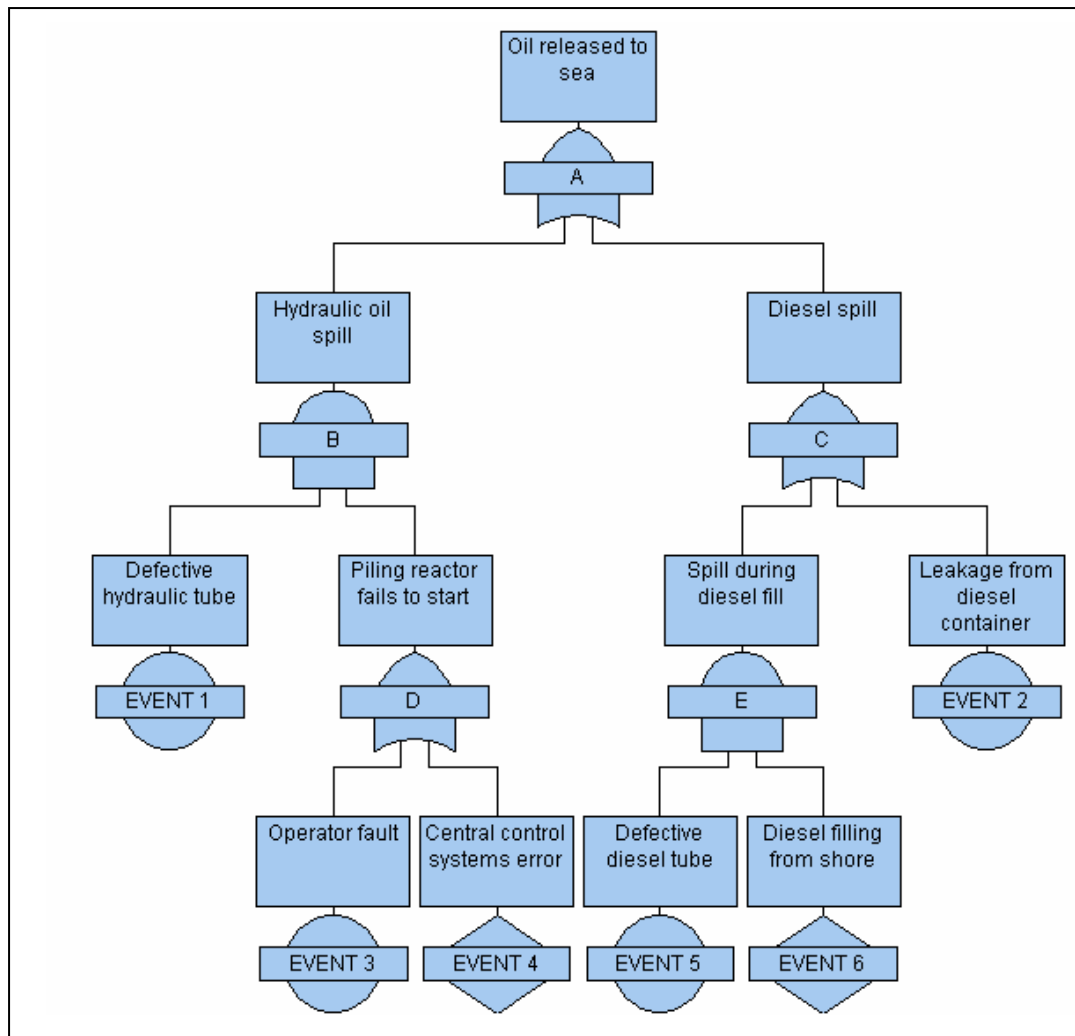


Figure 14: Fault Tree

Salient features of the fault tree are presented in Table 7.

Table 7. Event types and failure types

Event number	Type	Description (for prioritizing MCS)
1	Basic	Primary equipment failure
2	Basic	Primary equipment failure
3	Basic	Human error
4	Undeveloped	Secondary equipment failure
5	Basic	Primary equipment failure
6	Undeveloped	Secondary equipment function

### Step3. Identification of minimal cut set

Identification of minimal cut set can be done either by the Venn diagram method [53] or by the logical operator equation method [58]. The latter is suitable for medium sized fault tree analysis like the present case. It is important to note that the operators used in the equations are logical operators (AND = \*, OR = +) and not arithmetic operators.

$$\begin{aligned}
&\text{Gate to Top Event} = A \\
&= B+C \\
&= (1*D) + (2+E) \\
&= 1*(3+4) + 2 + 5*6 \\
&= 1*3 + 1*4 + 2 + 5*6
\end{aligned}$$

Thus the cut sets are: *1 and 3; 1 and 4; 2; 5 and 6.*

None of the cut sets contain redundant events (repeated events, e.g., 1, 1, 3) or supersets (cut sets that contain other complete cut sets, e.g., if 1, 3 is a cut set, a redundant cutset can be 1, 3, 4). Thus all of the cut sets are minimal cutsets.

#### Step 4. Qualitative analysis of the fault tree

After the fault tree has been constructed and the MCS have been identified, the next step is to prioritise the minimal cut sets to understand the importance of the basic events and judge if there is sufficient protection available against the occurrence of such events. Undeveloped events are not counted as part of the system but their importance is considered more subjectively.

Table 8 shows the minimal cut sets following the SINTEF guidelines.

Table 8: *Minimal cut set*

Priority	1	2	3	4
MCS	2	1,3	1,4	5,6
Types	Primary equipment failure	Primary equipment failure, Primary equipment failure	Primary equipment failure (repeat), Secondary equipment failure	Primary equipment failure, Secondary equipment failure

Both the top two cut sets in this case, contain no more than two events and are primary equipment failures. The operational setup thus needs to be reviewed in the light of these events.

Based upon the ranking the results of the FTA are to be used in the following operations at Veidekke:

*Judge acceptability:* The environmental management division would need to consult the site level staff whether to go ahead with business as usual, or alter the operation set up or stop proceeding further. These decisions are difficult to make without quantitative data about probability of occurrence and extent of damage that can be caused. However, the wide range of experience in Veidekke should help make qualitative decisions.

*Make recommendations for improvements:* If the decision is to modify the operational setup, the MCSs show the events that are most likely to create the top event to happen. These would require clear priority in improvements. The features of operational settings that can be changed by the FTA findings are – equipment modifications, procedural changes and administrative policy revisions to improve equipment maintenance and employee training.



*Resource allocation:* The resource for the improvements can be allocated according to the severity of the prioritized MCSs. Severity will be subjective, if not backed up with quantitative data but would generally involve the probability of the occurrence of the event and the financial costs associated with its impact.

#### 5. Quantitative analysis of the fault tree (optional)

Quantitative analysis of fault tree uses data for the probability and impact of the faults in a system. More specifically, these include - the probability that the top event occurs in a given period, mean time to top event failure, frequency of the top event [45]. If the fault tree yields Base Events in MCSs for whom reliability data are available (ref. § 5.2.2.2, Part I: Scenario I), the probability and/or impacts of the top event can be measured in quantitative units. Often these measures are not deterministic but probabilistic thus a simulation is possible. Monte Carlo simulation is a very common simulation that has been regularly used for FTA [59].

In this case, reliability data for none of the Base Events in the identified MCSs were found available and thus no quantified analysis was possible. However, given the nature of the Base Events, it is clear that it will be possible to estimate the number of occurrence of the Top Event from those of the Base Events, although the impact estimation will not be possible due to heterogeneity of the Base Events.

### 2.3. Conclusions of site specific risk analysis

In the absence of any quantitative data, the qualitative analysis can clearly help to establish the critical link from the base events to a top event. In this study, the Block II shows the concern areas which can be either directly or through conversion taken as the top event and a model of the controllable events, i.e., the basic events that can lead to the top event can be created and analysed. The strength of FTA is in its ability to step up the accuracy of the analysis by introducing numeric data as inputs. It can be safely assumed that once the process of FTA becomes customary at Veidekke, improvements to its accuracy will be suitably followed up [5].

### 2.4. Non-site specific risk assessment: Identification of the material

Of all the seven environmental concerns from the stakeholders, four (1, 2b, 2c, 2d, 3a) of them relate to concerns that can be *directly* mapped to material consumption, use or generation. The importance of materials used by Veidekke is thus quite clearly an area of concern.

In this step, the goal is to find a construction material that would be considered environmentally risky by the site personnel and then risk analysis will be pursued on one or more of its hazardous constituents.

#### Identification of the material to be assessed by EUSES method

Project Name: Oppgradering av Steen og Strøm Magasin

Project description: Upgrading of “Steen og Strøm” lounge in Oslo Sentrum shopping complex. Construction includes adding up 30 commercial unit retail spaces spread in seven floors, to the existing 55 at the beginning of the project.

Location: Oslo

Client: SK Steen & Strøm AS

Duration: June 2004 – July 2006  
Cost: NOK 80 Mn (approx.)

The site personnel were asked to send the name and amount of the three most environmentally harmful *products* used at the site. The results obtained are:

- Kaiflex Spesial Lim (approx. amount used 100 L)
- Byggsaum Hilti (approx. amount used 200 L)
- Motek Sponplate Lim (approx. amount used 50L)

As there was no indication of prioritising these three substances, a set of selection steps were established (these steps were based on common logic and maybe altered if felt necessary due to engineering judgment):

1. Choose the product that has any one of the constituent *materials* in N class (N = environmentally deleterious) in IUPAC nomenclature
2. Choose the N-class material that has maximum amount of usage amongst all N-class constituents in all products, using the percentage by weight constituency in the product .

According to these steps, *Byggsaum Hilti* and *Motek Sponplate Lim* were not considered as neither of their constituents contains an N-class material. Within *Kaiflex Spesial Lim*, several N-class constituents were found. The constituents are ranked in Table 9, according to the decreasing order of their percentage by weight presence in Kaiflex Spesial Lim.

Table 9: *Constituents of Kaiflex Spesial Lim (constituents marked \* are of N-class)*

Rank	Name	CAS Number
1	Cyclohexane*	110-82-7
2	Ethyl acetate	141-78-6
3	Acetone	67-64-1
4	2 Methyl pentane*	107-83-5
5	Heptane*	142-82-5
6	Butanone	78-93-3
7	n-Hexane*	110-54-3

Based on the selection rule, the choice of *material* to be studied is cyclohexane.

## 2.5. Performing the non-site specific risk assessment

Here, each of the steps required for assessment are described along with a description of what the step means. The data for the chemical cyclohexane is sourced entirely from IUCLID, unless mentioned otherwise.

EUSES is a system that allows a large amount of default values for specific products based on mathematical relationships, called Quantitative Structure-Activity Relationships (QSAR), between biological activity of a compound and computed (or measured) properties that depend on the molecular structure of the compound. This base dataset is used whenever IUCLID could not provide the data. Only one data set is not available in IUCLID and neither are the defaults supplied in EUSES, which is the eco-toxicological

data set. However, EUSES allows maximum and minimum values for the eco-toxicological dataset. Together with assessment factors that can account for errors in the chosen eco-toxicological value, eco-toxicological data can be assumed [36]. The assumptions are to be in line with the goal of EUSES to represent realistic or worse than realistic scenario but not worst case scenario.

Following the description, input values to the program are shown.

#### Selection of assessment types:

The assessment type refers to the protection goals to be studied and is classified into five groups:

1. Environment (i.e. aquatic and terrestrial organisms, sediment organisms)
2. Predators exposed via the environment (i.e. fish eating birds and mammals, worm eating birds and mammals)
3. Man exposed via the environment (i.e. via air, drinking water and food)
4. Man exposed to or via consumer products and
5. Man exposed at the workplace.

EUSES uses four different spatial scales for assessment - the personal scale, the local scale, the regional scale and the continental scale. The *personal* scale considers individual consumers or workers who are exposed directly to individual substances, preparations and to substances embedded in a solid matrix. The *local* scale considers the protection goals in the neighbourhood (1 km radius) of one large point source of the substance. The *regional* scale assesses the risks to protection targets due to all releases in a larger standardised Western European region with typical population and spans 200x200 km. The *continental* scale measures the fate and effects of pollutants on a even larger continental scale.

#### *Input*

- As in Veidekke, the lime is used in internal parts of the super-construction of a building, the impact will be the most in personal, local and to some extent in regional scales.
- The run mode is kept interactive, in order to navigate the system more easily
- Defaults are added

Hydrocarbon scale is not included as although cyclohexane can be obtained as a petroleum derivative, in Europe and Japan it is exclusively produced from hydrogenation of benzene [60].

#### Defaults

This section contains the defaults for the characteristics of the environmental compartments. The general parameter settings refer to a typical western European locality and can be changed. The values for the compartment settings are also typical and not worst case scenario.

#### *Input*

Set to default

#### Substance

The substance identification in the EUSES database is done by either CAS number or EINECS number.

The value of partition coefficient plays an important role in evaluating substances. It is defined as the ratio in which a given substance distributes itself between two or more different phases.

No data for the partition coefficients for solids-water ( $K_{oc}$ ), air-water ( $K_{aw}$ ) and human exposure under bio-concentration factor were offered in IUCLID. As the choice of partition coefficient factors greatly influences the distribution of the substance, it is advisable to use the default parameters in this case. However, the chemical class for  $K_{oc}$ -QSAR determination is also not provided in IUCLID. This was thus taken as the default QSAR. This however, should not be a major impediment, as the precise octanol-water partition coefficient ( $K_{ow}$ ) of cyclohexane has been used which would ensure a substantial degree of accuracy in the partition coefficient values.

Input parameters for degradation and transformation rates determine the fate of the substance in the environment. As empiric data on degradation processes are usually not available for the various compartments, they are extrapolated from standardised laboratory tests and are available specific to the substance in EUSES. Particularly for Cyclohexane, there have been recorded deviations from the IUCLID opinion of very low biodegradability but none have been conclusive [60]. For this study, the option chosen is "Ready biodegradability failing 10 day window".

Removal rate constants for soil are important to estimate, as they relate to the exposure of terrestrial organisms to pollutants. Moreover, crops can uptake pollutants that may eventually lead to contamination in human consumptions. Groundwater contamination is also considered as indirect exposure to humans although is generally considered only for the upper levels of aquifers. For this a simple soil media transport model is used in EUSES. Here the values are kept default.

### *Input*

#### *Substance identification*

CAS-No.: 110-82-7

EINECS-No.: 203-806-2

IUPAC name: Cyclohexane

Molecular weight: 84.16

Molecular formula:  $C_6H_{12}$

Melting Point: 6.5 C

Boiling Point: 80.7 C at 1010 hPa

Density: 780 kg/m<sup>3</sup> at 15 C

Vapour Pressure: 103 hPa at 20 C

Partition coefficient log  $K_{ow}$ : 3.44

Water solubility: 55 mg/l at 20 C

Flash point: -20 C

Henry's Law constant: 0.193 atm-m<sup>3</sup>/mole

*Partition coefficients and bioconcentration factors*

Chemical class for K<sub>oc</sub>-QSAR: Non-hydrophobic (default QSAR)

*Degradation and transformation input*

Ready biodegradability failing 10 day window

*Removal rate constants for soil*

Set to default

Release estimation

Characterisation and tonnage are important parameters that determine the overall impact of the use of the substance. It may be noted that it is only in this stage in EUSES that a percentage use of a substance in a particular region (200x200 km<sup>2</sup>) can be altered if found potentially risky. Put in a different way, it means that if a substance has been found to be beyond acceptable risk limits, the only way the company might still be able to use it, is by shifting the application of the substance to another area where the conditions may allow usage, although presumably at a lower magnitude.

In the use pattern screen, the uses of the substance in its six different life cycle stages can be put in. These stages are:

1. Production: The substance is manufactured, i.e. formed by chemical reaction(s) and processed in raw form.

In this case this is the stage where Cyclohexane can be used only as a raw chemical.

2. Formulation: Chemicals are combined in a process of blending and mixing to obtain a product or a preparation.

In this case, this is where Cyclohexane is mixed with other constituents of Kaiflex Spesial Lim.

3. Industrial use: During this phase, the substance as such is applied or used either as a constituent of a product or on its own.

This stage is where cyclohexane is in the most appropriate form to be used in.

4. Private use: This stage considers the use and application of substances on the scale of households.

No private use of cyclohexane is considered as it is deemed highly unlikely.

5. Service life: Diffusion, leaching or abrasion may cause long emissions.

Emission from cyclohexane cannot be ruled out as it is used in the near surface applications in buildings.

6. Waste treatment (disposal): At this stage the substance (or the products containing the substance) is disposed of with waste or waste water and treated and treated as sewage.

It is unlikely though that the building debris either as a whole or in part would find a way to sewage [5].

In this case, we assume that all of the cyclohexane produced is used for construction (industrial category – 16) except the production stage, where the raw form is assumed usable only in chemical industry.

### *Input*

#### *Characterisation and tonnage*

High production volume: Yes

Production volume of chemical in EU: 900 000 ton/yr

#### *Use pattern: Production stage*

Industrial category: 2 (Chemical industry: basic chemicals)

Use category: 55 (others)

Main category production: multi purpose equipment (lack of data)

#### *Use pattern: Other life cycle stages*

Industrial category: 16 (civil and mechanical engineering industry use)

Use category: 55 (others)

#### *Formulation:*

Main category formulation: Dedicated equipment, frequent cleaning

#### *Industrial use:*

Main category industrial use: Inclusion into a matrix

#### *Service life:*

Default

#### *Waste treatment:*

Default

### Distribution

Distribution models in EUSES calculate the spatial spread of the substance in two different scales – local and regional. Sewage Treatment Plant (STP) is treated separately for three scales – continental, regional and local. The data from the distribution forms the environmental concentrations in different environmental compartments (surface water, sediment, soil, air, groundwater, sewage treatment plant).

As mentioned before, a presumable fate of cyclohexane in STP is not likely although in the production stage of the substance, there can be a release of the waste water from the processing plant to STP. This would necessitate the manufacturing process data from cyclohexane producers of Kaiflex Spezial Lim used at Veidekke. As this data was unavailable, all the STP values are kept to default in the model.

Regional and continental distributions in EUSES show the parameters Predicted Environmental Concentrations (PECs), steady state fractions and steady state masses, on the scales - regional, continental and global. The value for these parameters are calculated based on the release fraction emissions and the release factors based on the physico-chemical properties, industrial category and use category of the substance. EUSES allows the value of regional PECs to be changed though, which would in turn change the steady state amount of that substance. Thus this provides a firm to conduct

its own tests in an alternate location that can be used if the PECs in the current settings render the use of the substance unacceptable.

Local distributions of the substance in EUSES show the local concentrations and depositions in as well as PECs for three life phases – production (pattern 1), formulation (pattern 2) and industrial use (pattern 2). The data for the service life and waste management life phases were not available.

#### *Input*

Default

#### Exposure

Exposure assessment is one of the most crucial steps in EUSES, as this determines the levels to which various life forms will be able to accept the exposure without any harmful effects. In EUSES, this is measured in five different categories – a) bioconcentration factor (using this, an estimation of the exposure to humans and predators through their liquid uptakes such as water is done); b) secondary poisoning (using PEC and the highest concentration without adverse effects, No Observed Effect Concentration (NOEC), an assessment is done if the aquatic ecosystem will be harmed by the substance), c) Human exposure through environment (a three staged process is used – first and assessment of presence of the substance in seven different consumption pathways, such as meat, milk, crops, inhalation of air etc; establishing a standard consumption pattern; combining concentrations with intake using an exposure scenario); d) consumer exposure (assessed the uses of the substance as a material use article, as opposed to be for food intake; uses three different scenarios – dermal, inhalation and oral); e) workers exposure (this is an external exposure assessment at workplace, not taking into account the absorption of the substance through physical contact).

For the current study, only three of the above five categories were available in EUSES, based on the input data. These three were – Secondary poisoning, Human exposed to or via the environment and Worker exposure.

The fate of the substance released is estimated by considering routes of exposure (according to the assessment types) and the basic data about the properties of the material. Thus unless a very certain value is available, the default values are the best option.

Workers exposure measures the exposure at the time of handling the material.

#### *Input*

Default except the following:

##### *Workers exposure input*

Workers exposure scenario title: Application of Kaiflex Spesial Lim

Process temperature: 12 C [5]

#### Effects assessment:

This step deals with the effects of the substance on the environment as well as on humans both directly and indirectly through environment. This step requires ecotoxicological values and does not offer any default values.

With the concept of environmental effects assessment, protection targets or *endpoints* must clearly be understood. These endpoints are – protection of organisms in aquatic, terrestrial, sediment ecosystems, micro-organisms in STP and top predators (birds, mammals that feed on fish or earthworms). The endpoints for humans are same as b, d, and e. The eco-toxicity data required for environmental risk assessment is usually extrapolated from the Predicted No Effect Concentration (PNEC) value, a concentration below which an unacceptable effect will mostly likely not occur. For human risk characterisation, direct empiric results are advised. Keeping these two in view, it maybe commented that these are probably the most difficult data to obtain as well as their modification will require fairly experienced judgment.

The goal of this step is to derive a PNEC for each of the endpoints in the study. In principle, the PNEC is calculated using a derived or observed contaminant concentration by an appropriate assessment factor. Such a concentration is usually either a statistically derived one which can be expected to cause death in 50% of the animals exposed for a specified time, called the median Lowest Concentration LC50, or a long-term NOEC. The choice of the assessment factor should be consistent with the overall goal of EUSES of representing worse than normal yet not the worse case scenario. Thus where the data is considered to be proved beyond doubt and is used as a basis for deriving other PNECs, assessment factors can be avoided. On the contrary, where there is no eco-toxicological data available, a high LC 50 can be combined with a high assessment factor.

The values of assessment factors are used according to TGD Table II-9.

The different scenarios for combining the value trends in default toxic data and default assessment factors are shown in Table 10.

Table 10. *Different weighing options possible in EUSES*

<b>Parameter</b> <b>Environmental Scenario</b>	<b>Toxic data (least lethal concentration)</b>	<b>Assessment Factor</b>
Best	High	Low
Reasonable 1	High	High
Reasonable 2	Low	Low
Worst	Low	High

No data was found available for the following parameters:

Toxicity data in sediments compartment – no data (can be assumed to be covered by the concentration in the surface water compartment, as it is lowly hydrophobic [60])

- Toxicity to terrestrial plants
- Toxicity for birds
- Toxicity data for mammals
- Toxicity for fresh water

The available data too showed incompatibility. Human effects input needed the No Observed Adverse Effects Level (NOAEL) as for mammals the contaminant concentration is derived indirectly, from the NOAEC in the food for mammals calculated for a daily consumption amount and adjusted according to the body weight



of the mammal species. In EUSES, the NOAEL data is to be supplied in mg/kg/day and the only data available for cyclohexane was in ppm. Thus there was incompatibility in data available.

Toxicological data for sediments' compartments: As cyclohexane is only moderately hydrophobic, its assessment is covered by the aquatic compartment.

Data for terrestrial: no data.

None of the PNEC, NOEC or NOAEL needed in EUSES are given in IUCLID. These are sourced from other EU publications or open literature. In Veidekke, situations like this would ever more emphasise on the need to engage competitive governmental authorities in the stakeholder deliberation.

### *Input*

#### *Input of Effects Data*

- *Microorganisms effect input*

EC 50 for microorganism: 49.4 mg/l

- *Aquatic effects input*

##### *Fresh water*

EC 50 for fish: 9 mg/l

EC50 for algae: 38.2 mg/l

EC 50 for Daphnia: 3.78 mg/l

##### *Marine*

L(E)C 50 for fish: 9 mg/l

L(E)C 50 for crustaceans: 7.32 mg/l

EC 50 for algae: 38.2 mg/l

##### *Fresh water and Marine sediment*

None

- *Terrestrial Effects Input*

None

- *Birds*

None

- *Mammal*

None

- *Human Effects Input*

Current classification: Xi-R38, Xi-R37

#### *Environmental PNECs:*

##### *Fresh water*

Toxic data: 1E+6 mg/l (according to Reasonable 1 scenario)

Assessment factor: 1E+4

#### *Marine*

Toxic data: 1E+6 mg/l (according to Reasonable 1 scenario)

Assessment factor: 1E+4

#### *Fresh Water and Marine sediment:*

Value supplied from QSAR by EUSES

#### *Terrestrial*

Value supplied from QSAR by EUSES

#### *Secondary poisoning*

None

(a risk assessment for secondary poisoning does not seem to be necessary, as it is not classified as “Toxic” or “Harmful” with at least R48 or R60-R64 [60]).

#### STP

LC50 microorganisms: 49.4 mg/l

#### Risk Characterisation

Risk characterization refers to the final step in EUSES where the use of the substance is found either acceptable or not based on the RCR values. A Risk Characterisation Ratio (RCR) is derived for each individual end-point, environmental and human. RCRs are derived by comparing exposure levels to suitable no-effect levels.

In the risk characterisation for the environment, this is done by dividing the PEC by the PNEC.

In the risk characterisation for human health, this is done by dividing the NOAEL by the estimated exposure level. This is the inverse of the RCR for the process for the environment and is called Margin of Safety (MOS). MOS should be calculated for each effect of concern possible through the intake of the substance via food, water and air. The estimation of MOS requires effect or no-effect toxic values such as NOAEL; a statistically derived expression of a single orally administered dose of a material that can be expected to cause death in 50% of the dosed animal, called acute oral LD 50; or the lowest concentration with observed adverse effects through consumption of food, called LOEC. For risks to workers, only surface contact toxicity values are used. For genotoxic carcinogens, the daily exposure is corrected using a factor of 8.4.

None of the reference MOSes required for calculation of the final MOSes was available in IUCLID; neither were the values of assessment factors. These were thus left out.

For environmental exposure risk characterization, the RCRs would need the PNEC values for the different compartments from the Effects category and use them with the PEC values. The values of the RCR are calculated on local and regional scales. No input of data was required for this as the data had been supplied already in the earlier stages.

*Input*

*Reference MOS for humans exposed to or via the environment*

None

*Reference MOS for workers*

None

*Environmental Exposure – Local and Regional*

None

None of the risks to humans to or via the environment or for exposure at work could be estimated as the MOS values were not available.

The final results of the EUSES model for cyclohexane in Kaliflex Spezial Lim is as follows:

Risk characterization result table for the environment

Usage/step	Report	Fr.water	IM	Marine	Fr.sed.	*10	Mar.sed.	*10	Soil	*10	STP	Fish	Mar.fish	Mar.top	Worm
1 "Production of cyc	Yes	3.91E-03		8.99E-03	3.91E-03		8.99E-03		4.85E-04		0.791	??	??	??	??
2 "Emissions from th	Yes	2.73E-03		6.29E-03	2.73E-03		6.29E-03		3.39E-04		0.554	??	??	??	??
2 "Emissions from th	Yes	9.36E-07		7.95E-08	9.36E-07		7.95E-08		8.67E-06		0	??	??	??	??
Regional	Yes	9.36E-07		7.95E-08	1.1E-06		7.88E-08		3.3E-08						

◀ Prev

▶ Next

▶▶ Finish

✖ Abort

🔍 Help

Figure 15. Risk characterisation of cyclohexane (from EUSES)

As all the RCR values are less than 1, the use of Kaiflex Spezial Lim can be rendered not environmentally damaging.

## 2.6. Conclusions of non-site specific risk assessment

This study shows that with the using the base set data of EUSES and the principles of the TGD, it is possible to conduct preliminary risk assessments of substances. However, the data is to be used only as indicative. Secondly, it is also suggested that both Reasonable 1 and Reasonable 2 scenarios are used in calculation and an average of those two may then be called a final reasonable set. A third iteration maybe done with the worst case scenario and an average between the final reasonable scenario and this worst case scenario may then be called a worse than normal scenario, which is what EUSES recommends to be used wherever possible (setting worst case scenarios are unrealistic and complex as one parameter usually effects more than one process - e.g. increasing the fraction organic carbon in soil will increase accumulation in soil, but at the same time will decrease leaching and bioavailability).

Using the recommendation, the equation to derive the most likely values of RCR becomes:

$$RCR_{\text{Worse than normal}} = 0.5[ \{ 0.5 (RCR_{\text{Reasonable 1}} + RCR_{\text{Reasonable 1}}) \} + RCR_{\text{Worst}} ]$$

It is this  $RCR_{\text{Worse than normal}}$  that should be communicated to the stakeholders to fulfil the need for the risk assessment. Further if this set of RCR values exceeds 1.0, a specialized study should be commissioned.

The study shows that there is acute lack of data for judging potential of human risks in IUCLID and EUSES, at least for cyclohexane. It will be imprudent to assume that if there no risk to the environment then no risk can be expected in indirect ways from the environment. The concern for human health with limited data thus remains an area of further study in applications of EUSES.

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## Appendix A. Environmental Impact Evaluation Proforma

### Vurdering av miljørisiko

Prosjektnavn og -nr:

Dato:

Deltakere ved vurderingen:

Område for risikovurdering: Hele anleggsprosessen / byggeprosessen					Sannsynlighet for "uønsket hendelse" der 1=lite, 2=middels, 3=stor Konsekvens av "uønsket hendelse" der 1=lite, 2=middels, 3=stor				
Miljørisiko er aktiviteter som gir middels til stor negativ miljøpåvirkning.					Tiltak skal redusere sannsynligheten for og konsekvensen av en uønsket hendelse. Velg om det skal settes inn tiltak eller ikke (Ja /Nei)				
Miljørisiko / Aktivitet	Uønsket hendelse	Miljøpåvirkning / Konsekvens	Forebyggende tiltak	Sannsynlighet 1 - 3	Konsekvens 1 - 3	Tiltak iverksettes (ja / nei )	Ansvar	Frist	Henvisninger
Graving, Misfarget jord, lukt og mangel på vegetasjon.	Oppdagelse og feil behandling av forurenset grunn	Fare for negative miljø- helseeffekter i omgivelsene.	Tiltakshaver er pliktig til å kartlegge ev. forurensning og ev. utarbeide og få godkjent en tiltaksplan for opprydding.						Rutine B 14.2.5
Graving, riving. Arkeologiske funn.	Ødeleggelse av kulturminne	Representerer egenart og variasjon. Del av vår kulturarv og identitet.	Kartlegging av kulturminner og kulturmiljø skal skje før prosjektstart i samarbeid med tiltakshaver og eventuelt kommunale myndigheter.						Rutine B 14.3.1
Graving, riving, produksjon	Vegetasjon skades	Reduksjon av biologisk mangfold	Vegetasjon som skal bevares bør merkes og inngjerdes hvis mulig.						

Prosjektering, innkjøp	<b>Bruk av produkter fra regnskog</b>	Dårlig ressursutnyttelse. For stor miljøbelastning.	Unngå bruk av regnskogstømmer / tropisk trevirke som f.eks. merbau, mahogni og teak. Se etter miljøsertifisering signert av FSC.					<a href="http://www.regnskog.no">www.regnskog.no</a> Hvis du er usikker, kontakt <a href="mailto:timber@rainforest.no">timber@rainforest.no</a>
Prosjektering, innkjøp	<b>Bruk av produkter med unødvendig stor miljøbelastning</b>	Dårlig inneklimatekst. Dårlig grunnnet emisjoner. Dårlig ressursutnyttelse. For stor miljøbelastning.	Substitusjonsplikten. Bruk databladene aktivt. Unngå bromerte flammehemmere					Rutine B 14.1.2 Rutine B 13.6.1
Innkjøp av nye isolerglassruter	<b>Returordning for PCB fungerer ikke, PCB vil havne i naturen</b>	PCB er en svært alvorlig miljøgift som ikke må spres i naturen. PCB er kreftfremkallende, skader forplantningsevnen og akkumuleres i næringskjeden.	Sjekk at produsent / importør er med i returordning. Etterspør dokumentasjon.					Avfallsforskriften, kap 14 <a href="#">Kasserte PCB-holdige isolerglassruter</a>
Prosjektering, innkjøp, produksjon	<b>Stor avfalls-generering</b>	Ressursforbruk og miljøbelastning er større enn nødvendig.	Tiltak settes inn i tidlig fase for å redusere mengdene spill, kapp og emballasje.					Rutine B 14.1.3
Produksjon	<b>Uheldig oppbevaring og håndtering av ulike kjemikalier og spraybokser</b>	Miljøskadelige stoffer og farlig avfall kan skape forurensning eller skade på mennesker, dyr eller natur.	Bruk datablader, CoBulider					Rutine B 14.2.4 Rutine B 13.6.1
Bruk av maskiner, fylling av drivstoff	<b>Utslipp til jord, vann, elv, grunnvann</b>	Fare for negative miljø- og helseeffekter i omgivelsene.	Godt vedlikeholdte maskiner, dobbeltmantlet lagertank, unngå sol, god beredskap ved uhell, absorberent. Bruk datablader.					Rutine B 13.6.1
Graving, riving, produksjon	<b>Støy</b>	Sjenanse med fare for helseskade	Støyreducerende verktøy og andre støyreducerende tiltak, informasjon til berørte parter					Rutine B 14.3.2

Graving, riving, produksjon	<b>Støv, ute</b>	Sjenanse	Vanning, salting, informasjon til berørte parter						
Graving, riving, ombygning, produksjon	<b>Uheldig avfalls-håndtering</b>	Forurensning eller skade på mennesker, dyr og natur. Dårlig ressursutnyttelse	Avfallsplan utarbeides.						Rutine B 14.2.2
Riving, ombygning	<b>Ingen eller uheldig miljøsanering</b>	Miljøskadelige stoffer og farlig avfall kan skape forurensning eller skade på mennesker, dyr eller natur.	Ved riving og ombygning skal miljøsaneringsrapport utarbeides som et vedlegg til avfallsplanen. Her kartlegges miljøfarlige stoffer og farlig avfall. Dette fjernes og fraktes til godkjent mottak før resten av bygget/anlegget rives.						Rutine B 14.2.3
Riving og nybygg avfallshåndtering	<b>Farlig avfall havner på avveie</b>	Miljøskadelige stoffer og farlig avfall kan skape forurensning eller skade på mennesker, dyr eller natur.	Farlig avfall skal alltid kildesorteres og fraktes til godkjent mottak. Både riving og nybygg gir farlig avfall. Samarbeid med avfallstransportør. Bruk databladene						Rutine B 14.2.4
Produksjon, avfallshåndtering	<b>Ingen eller liten grad av kildesortering</b>	Dårlig ressursutnyttelse.	Tilrettelegge for effektiv kildesortering gjennom samarbeid med avfallstransportør. Unngå å sende avfallet til deponi, frem ombruk og materialgjenvinning.						Rutine B 14.2.2
Bruk av maskiner og annet utstyr for produksjon. Oppvarming, lysbruk	<b>Høyt energiforbruk</b>	Global oppvarming. Dårlig ressursutnyttelse.	Bevisst valg av energikilder - og et bevisst forbruket av disse. Bruk "lysfølere", termostater, tidsbrytere, isolerte lagercontainere. "Ikke fyre for kråka".						Rutine B 14.4.1

Produksjon "tett bygg"	etter	<b>Ikke fokus på "Rent Tørt Bygg" (RTB)</b>	Dårlig inneklima for sluttbruker grunnet fukt og støv.	Forebygge støv, smuss og fuktskader i byggeperioden. Prosjektet definerer nivået for RTB.							Rutine B 14.1.4
Produksjon "tett bygg"	etter	<b>Støv, inne</b>	Dårlig inneklima for sluttbruker	Tydeliggjøre krav til støvnivå. Gjennomføre målinger underveis. Fokus på ventilasjonskanaler og over himling.							ev. rutine B 14.1.4
Produksjon "tett bygg"	etter	<b>Fukt</b>	Dårlig inneklima for sluttbruker	Riktig lagring av materialer. Tett tak tidlig. Gjennomføre nødvendige fuktmålinger.							ev. rutine B 14.1.4

## Appendix B. Trend Analysis

The initial study of the Trend Analysis drew upon directly from the six strategic areas given by Norwegian Ministry of Local Government and Regional Development in its document, ” *Environmental Action Plan for the Housing and Construction Sector, 2005-2008*” (EAP 2005-2008). This document shows how municipal authorities are to deal with strategic goals in the housing and construction sector. The idea behind this step is to

- Check if any regulation is in the pipeline for the housing and construction sector that can affect the operations of a construction contractor. Although new regulations give sufficient time for any change(s) they might imply, a prior knowledge of them is better for making upstream changes in business planning.
- To see if there is a complementary action that Veidekke can undertake which is, though not a requirement, in unison with the efforts at the municipal level. Cooperation with regulatory authorities is a hallmark for proactive environmental management.

The results are as follows:

### EAP 05-08 Theme 1: To enhance spatial efficiency and attention to biodiversity

Norway has been one of the earliest (May, 2000) signatories to Convention on Biodiversity (CBD) and with the recent focus of CBD on the role of business in sustainable development, it is no secret that industries in Norway will feel a greater need to contribute towards protecting biodiversity and spatial efficiency<sup>2</sup>. Preservation of open landscapes, indoor climate and preservation of biodiversity are some of the key areas to focus on, as per the Norwegian Ministry of Local Government and Regional Development<sup>3</sup>.

A detailed analysis of this theme reveals that this idea is underpinned by the aspiration of better spatial planning on all the counts, such as spatial efficiency and protection of biodiversity. This theme is mainly targeted to municipalities and other local planning authorities as they are the entities to decide upon which part of a particular area should be allowed to be developed. It is at that juncture that concepts of spatial efficiency and biodiversity come into play as once a plot has been allowed to be developed the contractor has to follow clearly set instructions about preservation of biodiversity and cultural remnants or similar articles worth preserving.

This being the situation, engaging in a trend analysis for the regulations in this field, given the nature of Veidekke’s activity is precluded. There are however several new measures in the pipeline in this domain, such as – a simplified environmental assessment process/regulation for the buildings, review of the nature protection act, strengthening of regulations to stop losses to bio-diversity by 2010 and an added accent on citizen

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<sup>2</sup> Convention on Biological Diversity, “Status of Ratification and Entry Into Force,” April 2006; <http://www.biodiv.org/biosafety/signinglist.aspx?sts=rtf&ord=dt>

<sup>3</sup> Norwegian Ministry of Local Government and Regional Development, *Environmental Action Plan for the Housing and Construction Sector, 2005-2008*. Oslo: Kommunal- og regionaldepartementet Publisering, 2004, pp. 14

participation in regional planning by means of a greater utilisation of Cities' Forum (Storbyforum)<sup>4</sup>. Given this array of developments it will be quite prudent to have an appropriate authority from an appropriate level of environmental ministry competent in providing the necessary information about these changes that might strategically affect the business of Veidekke, in the stakeholder deliberations.

EAP 05-08 Theme 2 : To reduce energy consumption in building stock

Reduction of energy utility in built up environment has been one of the key elements of focus in environmental deliberations in the EU for some time<sup>5</sup>. The two issues that stand out in this respect are the needs to conserve energy and increase the usage of renewable energy<sup>6</sup>. A few targets have been set for the allowable amount of electricity and energy usage in the building stock for the coming years. Although Veidekke is not an electricity design contractor or into managing buildings, both of which would relate to energy consumptions in Veidekke's operations in a bigger way, it can still contribute proactively by detailing the type of energy being used to operate its machinery as well as work with the design contractors to promulgate the sustainable design concepts.

A qualitative study of the probable changes in the energy mix can be beneficial for the longer run for Veidekke, which can easily be achieved by a representation from appropriate governmental authorities. A quantitative trend analysis of the reduction in energy use will also be an indicator of the company's performance in energy efficient operation. This can be done in two ways that are as follows:

- By comparing the year over year energy usage to built up area (or revenue earned) ratio

*Shows energy efficiency in the construction process of Veidekke. This will be useful to benchmark the annual performance.*

- By comparing the allowable limits of energy usage in building construction from the Norwegian authorities for at least the last 10 years

*Shows a trend over the last decade in allowed energy supply patterns in Norway. This will be a useful guidance for the type of constructions that Veidekke is to undertake and where it puts the planned constructions of Veidekke.*

EAP 05-08 Theme 3 : To document and reduce the use of hazardous substances in construction

Usage of hazardous substances in construction is one of the earliest recognised perils of construction industry. Of late, a particular focus in Norway has been non-point source pollution in the construction industry<sup>7</sup>. As ground water leaching and other solid media percolation are the major modes of transport of pollutants in construction, hazardous or phase out materials often pose high risks to the construction site, even if present in small quantities. Regulations in this field are often very strict and rapidly emergent. The

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<sup>4</sup> Norwegian Ministry of Local Government and Regional Development, pp. 15

<sup>5</sup> Commission of The European Communities, "Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the energy performance of buildings," May 2001; [http://europa.eu.int/comm/energy/library/en\\_bat\\_en.pdf](http://europa.eu.int/comm/energy/library/en_bat_en.pdf)

<sup>6</sup> Norwegian Ministry of Local Government and Regional Development, pp. 18

<sup>7</sup> Norwegian Ministry of Local Government and Regional Development, pp. 19

Directorate of Public Construction and Property, Norway (Statsbygg) has already announced that in the period 2005-2009 it will limit the usage of environmental impacts through the choice of constructional materials<sup>8</sup>. This comes after a directive banning the use of all environmentally hazardous materials by 2020<sup>9</sup>.

While the choice of energy source (see Theme 2) for a construction contractor would inevitably open up a few intermediaries to come in (such as electricity suppliers), the choice of building material poses a rather uncomplicated question to Veidekke. If materials for construction are chosen carefully, much of the risk associated with the selection of the materials is going to be taken care of.

The trend analyses for this section would focus on the phase out list followed at Veidekke. A qualitative study hinting at various groups and subgroups of materials that have been added to the phase out list together with a quantitative study of their allowed amounts will form a well rounded study on the future risks with the choice of construction materials.

EAP 05-08 Theme 4 : To reduce construction waste and increase recycling/re-use of materials

With a firm focus on reusability of construction materials the fourth theme refers not only to reduce waste and increase recycling, but also emphasises on the amount of waste as a percentage of the total built up area. Amongst other measures source sorting of waste is prioritised and is advocated as a measure helping the success and ease of increasing recycling. Currently a good deal of focus on recycling is observed in Veidekke with an overall recycling rate of 40% of the construction waste<sup>10</sup>.

A qualitative study of the new materials that have come to be recognised as waste over the last 10 years will possibly reveal a trend towards a few distinguishable groups that are going to be even more restricted in the coming years. This will help Veidekke have an idea about the possible risks with the use of certain groups of construction materials or certain types of construction processes that give rise to those types of waste.

A quantitative study in the amount of waste allowable as a percentage of the total building stock or as a ratio of some other fixed reference will help getting at a possible figure of how the allowable amounts are going to be like in future.

EAP 05-08 Theme 5 : To focus on high quality and good building and environmental design

Design of buildings is not a primary concern for Veidekke as being a construction contractor the design functions are handled by architecture firms that are outside the organisational domain of Veidekke. Consistent with Veidekke's aspiration to be environmentally superior in the industry however, it is imperative that the firm works closely with the design consultancies to ensure a high standard of quality and environment in the construction that it undertakes. This is also in line with the suggestion following the electricity mix in Theme 2.

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<sup>8</sup> Norwegian Ministry of Local Government and Regional Development, pp. 22

<sup>9</sup> Norwegian Ministry of Local Government and Regional Development, pp. 22

<sup>10</sup> Veidekke, *Annual Report 2004*. Oslo: Network Produksjon. 2005, pp. 51

EAP 05-08 Theme 6 : To ensure environmentally sound building management and maintenance

The current nature of business at Veidekke Entreprenør AS does not include building management, as it is wholly into outright sale of its constructions. However, with a view towards possible future expansions in the building management sector as well as clear indications set by the Directorate of Public Construction and Property to implement EMS related legislation related to NS-EN 96:14001<sup>11</sup>, it will be pertinent to keep a tab on the developments. There is an accent on using life cycle costing related methods for building management<sup>12</sup> from the directorate which goes on to show that if there is an building management related regulation in future, it may well have certain environmental practice requirements during the construction phase as well, as technically, building management covers the construction phase too.

Though it will be quite redundant to actually carry out a study in this regard, it sure will be an efficient measure to have a representation from the concerned environmental authorities in the stakeholder deliberations who can update Veidekke about the possible changes in the pipeline.

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<sup>11</sup> Norwegian Ministry of Local Government and Regional Development, pp. 31

<sup>12</sup> Norwegian Ministry of Local Government and Regional Development, pp. 29



**Appendix C. Contribution of the framework in reducing risks to the ALARP category vis-à-vis the current EMS practice**

<b>Project Stage</b>	<b>Elements in demonstration that risks are in the ALARP region</b>	<b>Current practice of EMS</b>	<b>EMS with the framework</b>
Choosing between options or concepts; Detailed design	Risk assessment and management according to good design principles	No comprehensive (or quantitative) environmental risk management practice	Assessment clearly articulated, management (treatment of risk) suggested
Choosing between options or concepts; Detailed design	Risk considered over life of facility and all affected groups considered	No	Yes
Choosing between options or concepts;	Demonstration that chosen option is the lowest risk or justification if not	No	Yes
Choosing between options or concepts;	Societal concerns met, if required to consider	Not applicable	Not applicable
Choosing between options or concepts;	Demonstration that duty-holder's design safety principles meet legal requirements	Yes (no legal complication due to environmental causes till the time of documentation)	Implicit
Detailed design	Use of appropriate standards, codes, good practice etc. and any deviations justified	Yes	Yes

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