Risk management and sustainability

Development of an extended model for assessment of investments in fire protection measures

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Titel: Riskhantering och hållbar utveckling: Framtagande av en utökad modell för bedömning av investeringar i brandskyddsåtgärder.

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Abstract
Sustainability is an ever increasing field of interest in business management. However, the notions of sustainability are elusive and its implications are not always clear. What is clear though is that being sustainable can enhance a corporate organisation's competitive advantage. Risk management in general, and fire protection in particular, can be argued to inherently provide benefits of a sustainability nature. This implies that the use of investment in fire protection can help make organisations more sustainable. However, present methods for investment assessment are based on old-fashioned economic reasoning that do not account for sustainability in a desirable manner. Therefore, this thesis investigates how the increasing attention to sustainability interrelates with the key concepts of risk management and how these connections can be utilized to further develop the investment assessment procedure to better account for sustainability. An attempt is made to develop a semi-quantitative model for assessment of investments in fire protection measures. The model is based on a multi-attribute utility theory and uses an ordinal assessment scale to rate a number of sustainability factors that are chosen to specifically represent the consequences which may occur due to fires in industrial organisations.

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Foreword

Nu är det nog dags att skriva på svenska (Now I think it is time to write in Swedish). För över ett år sedan började jag att fundera på vad detta examensarbete skulle handla om. Inte helt oväntat gick tankarna förvirrat åt många olika håll. Nu sitter jag här, knappt en vecka innan deadline, med ett omfattande material framför mig. Det har på många sätt varit ett spännande och lärorikt år. Inte minst tack vare all värdefull återkoppling som jag fått från min handledare Ulf Paulsson vid Lunds universitet, och min externa handledare Tobias Ekberg på FM Global. Ni ska båda ha ett stort tack för all hjälp och stöttning. Ett stort tack ska också Lars Stenblom på Trelleborg AB ha, eftersom han vid flera tillfällen tagit sig tid att kommentera och diskutera mitt arbetes fortskridande. Dessutom vill jag rikta ett tack till Johan Lundberg på Alfa Laval som lät mig störa med en diskussion om ämnet, samt de som bemödade sig med att besvara min förfrågan om en utvärdering. Era kommentarer har varit ack så värdefulla.

Vid det här laget är produkten av arbetet färdig. Ja, så gott som färdig i alla fall. Säkerligen finns det otaliga justeringar att göra. Säkerligen finns det också många helt fundamentala förändringar som skulle kunna göras. Men jag känner mig nöjd och belåten. Eller kanske trött? Oavsett vilket så ser jag med glädje fram emot att få presentera arbetet för dem som vill höra. Till dess så träder jag ut ur min ”examensarbetarens bubbla”, och ägnar åter tid åt min åsidosatta omgivning. Det ska bli trevligt att träffa mina nära och kära igen.

Robin Zetterlund,

den 14 februari 2011 – Alla hjärtans dag.

Executive summary

As the world is developing, social and environmental impacts are becoming increasingly significant. The world population is growing inexorably, and along with it the consumption of food and fresh water. Industrialisation and technological progress has made the world a place where our way of living is starting to leave significant scars. People are becoming ever more aware of the damages that industrialisation and climate change can cause to our planet. Due to the rising awareness of how industrial activities could lead to environmental impacts, the notion of sustainability was born. In 1987 the World Commission on Environment and Development presented an ethical definition of sustainable development which stated that *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*. This definition of sustainable development indicated that there was more to development than just economic progress. Today sustainability is interpreted as comprising the three dimensions *economic* (1), *environmental* (2), and *social* (3) sustainability, which are commonly known as the *three pillars of sustainable development* (refer Figure 1).

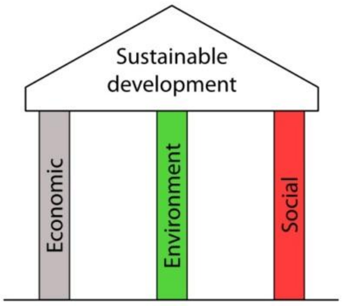


Figure 1: The three pillars of sustainable development.

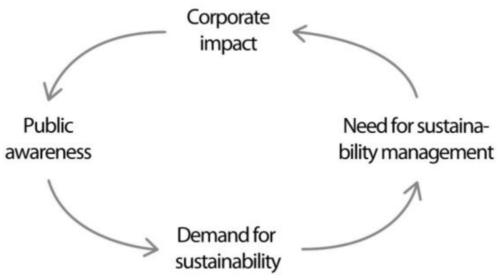


Figure 2: Schematic illustration of the importance of corporate sustainability.

Sustainability has in recent years become an important aspect of corporate management. As shown in Figure 2, public awareness of how industrial activity could lead to environmental impacts means that the general public also places a demand on corporations to consider sustainability. Corporations need to adhere to this demand and practise some kind of sustainability management, aimed at reducing the impact that the corporation causes on the surrounding environment. As such, being sustainable has become a feature that can help corporations increase their competitive advantage.

The management of an organisation have a responsibility towards its stakeholders to manage any risks that may threaten the organisation's goals. Consequences in terms of, for example, production disruption can lead to significantly increased costs. Although there are many different types of risks that can pose a threat to an organisation, fire is one that is particularly examined in this report. In the event of a fire a corporate organisation may suffer significant losses in terms of property damage, down time due to recovery, loss of income, loss of market shares, damaged stakeholder relations, damaged reputation etc. Thus, investment in fire protection can be an essential consideration to the organisation. However, assessment of investment in fire protection may be difficult to conduct.

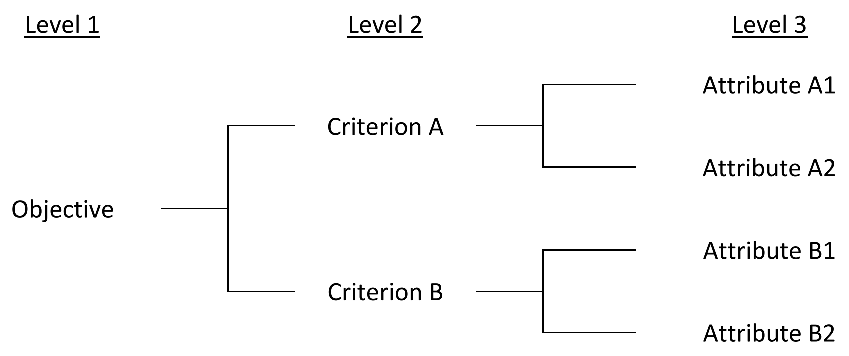
Traditional methods for investment assessment include net present value (NPV), internal rate of return (IRR), and pay-back (PB). All of these and many other methods for assessing capital investments are to some extent based on monetary valuation of a set of incoming and outgoing cash flows. Translating social and environmental aspects into monetary terms is a primary difficulty in assessing sustainability related investments. What is for example the environmental value of a forest? In fact, most existing methods for investment assessment do not provide an appropriate way of including sustainability related aspects such as social and environmental impact. Even on a national economic level insufficiencies exist; the gross domestic product (GDP), which is the key measurement of development, fails to account for environmental impacts. For example, as the supertanker Exxon Valdez ran aground off the Alaskan coastline in 1989, all the money spent on the recovery was counted as positive expenditure, which meant that the entire incident boosted the GDP. This shows that the traditional ways of assessing investment are not suited to account for sustainability aspects. In a similar manner, assessment of investment in fire protection is difficult using traditional methods. Assessing the costs of fire protection is relatively straight forward, but what should be taken as income? Intuitively one understands that there are several benefits with fire protection but trying to express them in terms that make them comparable with the costs is a tricky task.

Fire protection can be argued to inherently help increase an organisation's sustainability. Fire protection and sustainability share the common goal of making the world a better place since they both strive to preserve and maintain. Examples of how certain sustainability factors are impacted by fires include; the release of toxic materials and greenhouse gases into the air, significant consumption of water for fire fighting purposes, leakage of contaminated fire fighting water run-off into the soil or nearby aquifers, increased costs and environmental impacts due to reparation or rebuilding (including production and transports of new building materials), health impacts to both workers and the general public, loss of jobs, risk of permanent shut-down of heavily damaged production units, and local community impact due to lost jobs etc. Addressing potential fire risks can thus obviously be of significant value for increasing sustainability.

In this thesis an extended model for assessment of investment in fire protection measures is developed. The basic idea of the model is that it should strive to present the benefits of fire protection in a wider perspective, more specifically a sustainability perspective. For this purpose a semi-quantitative model is developed by inspiration of a multi-attribute utility theory. It uses scoring on a qualitative scale to assess how certain sustainability factors (attributes) are impacted by a fire. The assessment scoring is made according to the following ordinal scale:

1. Insignificant impact
2. Minor impact
3. Significant impact
4. Major impact

The model is constructed with three levels denoted objective, criterion, and attribute respectively. The below figure shows the structure of the model:

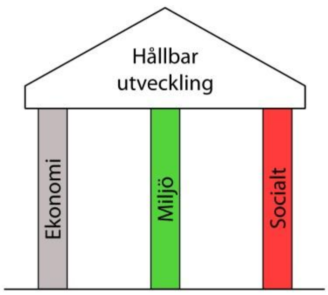


Scoring is made at level 3 (attributes). The model further includes weighting at level 1 and 2 in order to provide results in terms of weighted scores. The model as developed includes 3 objectives, 8 criteria, and 26 assessable attributes.

A brief evaluation of the model indicates that it raises awareness of sustainability, incorporates sustainability into the investment decision process, and accentuates the benefits from fire protection in a sustainability perspective. The major strength with the model is that it provides flexibility in the sense that it can be modified to include whatever aspects the organisation finds suitable. The use of weights also provides an opportunity for the organisation to decide the relative importance of the included aspects. However, in order to produce a fully operational model for the assessment of investment more effort is needed, as well as more research.

Sammanfattning

I takt med att världen utvecklas blir sociala och miljömässiga konsekvenser mer och mer betydande. Världens befolkning växer obönhörligen, och tillsammans med denna även konsumtionen av mat och vatten. Industrialisering tillsammans med tekniska framsteg har gjort att vårt sätt att leva numera sätter tydliga spår på vår planet. Människor runt om i världen har blivit alltmer medvetna om att industrialisering och klimatförändringar kan orsak långvariga skador på naturen, och sedermera även på oss människor. I samband med att denna medvetenhet vuxit fram har också begreppet hållbar utveckling kommit till världen. 1987 presenterade Världskommissionen för miljö och utveckling en etisk definition av hållbar utveckling som innebär att *hållbar utveckling är utveckling som tillgodoser dagens behov utan att äventyra framtida generationers möjlighet att tillgodose sina egna behov*. Denna definition av hållbar utveckling angav att utveckling innebär mer än bara ekonomiska framsteg. Dagen tolkning av hållbar utveckling består av de tre dimensionerna ekonomisk (1), miljömässig (2) och social (3) hållbarhet. Dessa tre dimensioner kallas även för *de tre pelarna för en hållbar utveckling* (se figur 1).



Figur 1: De tre pelarna för en hållbar utveckling.

Figur 2: Schematisk illustration av vikten av hållbar utveckling inom företag.

Hållbarhet har under de senaste åren också blivit en viktig del inom företagsledning. Som figur 2 antyder kan allmänhetens ökande medvetenhet om miljöpåverkan från industriell verksamhet innebära att allmänheten också ställer krav på att företag beaktar hållbarhet. Företagen måste försöka hantera kraven genom att eftersträva hållbar utveckling, vilken bör vara inriktad mot att minska företagens påverkan på sin omgivning. I och med detta har hållbar utveckling blivit ett begrepp som företag kan använda för att öka sina konkurrensfördelar.

En organisations ledning har ett ansvar gentemot dess intressenter att hantera eventuella risker som kan hota organisationens mål. Konsekvenser i form av exempelvis produktionsstörningar kan leda till kraftigt ökade kostnader. Även om det finns många olika typer av risker som kan utgöra ett hot mot en organisation, är brand en risk som särskilt undersöks i denna rapport. En brand kan leda till påtagliga skador som till exempel egendomsskador, produktionsstopp under återuppbyggnad, förlorad inkomst, förlorade marknadsandelar, skadade kundrelationer, skadat rykte osv. Investeringar i brandskydd kan således vara ett viktigt övervägande för organisationen. Men investeringsbedömningar gällande brandskydd kan dock svåra att genomföra.

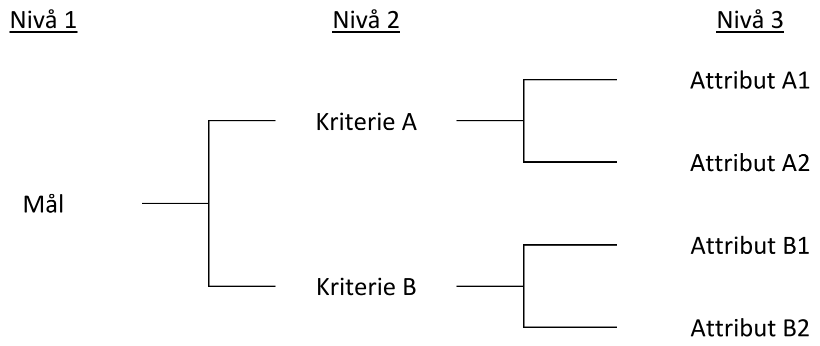
Traditionella metoder för investeringsbedömning inkluderar nuvärdesmetoden (kapitalvärdesmetoden), internräntemetoden, och pay back-metoden. Alla dessa metoder för bedömning av kapitalinvesteringar är delvis baserat på monetär värdering av en rad långsiktiga betalningskonsekvenser. En betydande svårighet är dock att omsätta sociala och miljömässiga aspekter i monetära termer. Vilket är till exempel det miljömässiga värdet av ett parti skog utryckt i kronor och ören? Faktum är att de flesta befintliga metoder för bedömning av investeringar inte på något lämpligt sätt beaktar aspekter som relaterar till hållbar utveckling. Även på en nationalekonomisk nivå är finansiell bedömning bristfällig; bruttonationalprodukten (BNP), som i dagsläget är det yttersta måttet på utveckling, misslyckas i princip helt och hållet att ta hänsyn till miljöpåverkan. När tankfartyget Exxon Valdez gick på grund utanför Alaska 1989, räknades alla omkostnader för sanering som positiva, vilket innebar att hela incidenten utgjorde ett rejält lyft för Alaskas BNP. Traditionell investeringsbedömning bygger på samma ekonomiska teorier som BNP och detta visar att de traditionella sätten att bedöma investeringar inte främjar hållbar utveckling. På ett liknande sätt är bedömning av investeringar i brandskydd svårt att göra med traditionella metoder. Att bedöma kostnaderna av brandskydd är kanske relativt enkelt, men hur ska nyttan uttryckas i monetära termer? Intuitivt inser man att det finns flera fördelar med brandskydd men att försöka uttrycka dem på ett sätt som gör dem jämförbara med kostnaderna är en besvärlig uppgift.

Brandskydd kan anses ha inneboende egenskaper av hållbarhetskaraktär. Brandskydd och hållbar utveckling delar det gemensamma målet att göra världen en bättre plats. Exempel på hur hållbarhetsaspekter kan påverkas av brand inkluderar utsläpp av giftiga ämnen och växthusgaser till luften, konsumtion av vatten i samband med släckarbete, avrinning av kontaminerat släckvatten till mark och vatten, kostnader för sanering av kontaminerad mark och vatten, rättsliga kostnader i samband med kraftig miljöpåverkan, kostnader för återuppbyggnad (inklusive produktion och transporter av nya byggnadsmaterial), hälsoeffekter på både arbetstagare och allmänheten, förlorade arbetstillfällen, inverkan på det lokala samhället på grund av förlorade arbetstillfällen osv. Att hantera potentiella brandrisker kan således vara av betydande värde i strävan efter hållbar utveckling.

I detta examensarbete utvecklas en utökad modell för bedömning av investeringar i brandskyddsåtgärder. Modellens grundläggande idé är att försöka presentera fördelarna med brandskydd i ett bredare perspektiv, närmare bestämt ur ett hållbarhetsperspektiv. För ändamålet utvecklas en semi-kvantitativ modell med inspiration av multiattributbeslutsteori. Modellen använder en kvalitativ poängsättning för att bedöma hur ett antal hällbarhetsaspekter (attribut) påverkas av en brand. Poängsättningen görs enligt följande ordinala skala:

1. Obetydlig påverkan
2. Liten påverkan
3. Betydande påverkan
4. Avsevärd påverkan

Modellen är uppbyggd i tre nivåer som benämns mål, kriterie samt attribut. Figuren nedan visa modellens struktur:



Poängsättningen sker på attributen i nivå 3. Modell innehåller viktning vid nivå 1 och nivå 2 så att en total viktad poäng kan beräknas för varje alternativ som ingår i bedömningen. Såsom modellen presenteras i rapporten innehåller den 3 mål, 8 kriterier och 26 attribut.

En kort utvärdering av modellen anger att den bidrar till att öka medvetenheten kring hållbar utveckling, introducerar hållbar utveckling i beslutsprocessen för investeringsbeslut och understryker fördelarna med brandskydd ur ett hållbarhetsperspektiv. Den stora styrkan med modellen är att den erbjuder flexibilitet i den meningen att den kan ändras till att inkludera de aspekter som organisationen finner mest lämpliga. Användning av viktad poängsättning ger också organisationen en möjlighet att själv bestämma de inkluderade aspekternas relativa betydelse. För att producera en fullt fungerande modell för bedömning av investeringar krävs dock ytterligare ansträngningar, liksom mer forskning.

Table of Contents

Chapter 1 – Introduction

This document constitutes the final thesis report for a Master of Science degree in risk management and safety engineering, and a Bachelor of Science degree in fire protection engineering. The thesis has been completed with support from FM Global as an external mentor entity and Trelleborg AB who contributed with valuable input and feedback on the thesis work. This report has been written partly at the premises of Lund University, and partly at the premises of FM Global's branch office in Stockholm.

This chapter presents a background to the project, as well as its purposes and objectives.

1.1 Background

The term *sustainable development* (SD) originated in the 18th century where it was used in forestry to control the number of trees cut down, as a means to ensure a continuous supply of wood for forthcoming generations (Ebner & Baumgartner, 2006). Lately the terms of sustainability and SD have also become increasingly popular in enterprise management. Epstein claims that "The challenge has moved from "whether" to "how" to integrate corporate social, environmental, and economic impacts – corporate sustainability – into day-to-day management decisions…" (Epstein, 2008, p.19). However, since the discussions on sustainability in recent years have risen significantly the subject has become broad and imprecise and without a common definition (Ebner & Baumgartner, 2006). Despite that there are many different interpretations of the concept, one of the most frequently used ethical definitions of SD is that adopted by the World Commission on Environment and Development (WCED); "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCED, 1987). This emphasises that the concept of SD includes the consideration of both the present and the future. In line with this, Krysiak (2009) notes that sustainability can be interpreted as a framework for assessing how decisions in the present may impact individuals in the future.

As indicated above, over the years the understanding of SD has evolved into comprising of three dimensions, namely economic (1), environmental (2) and social (3) sustainability respectively; a concept that is sometimes referred to as the three pillars of sustainable development (Adams, 2006). The notion of sustainability as three pillars implies that all three dimensions are equally important, which might indeed be a desirable goal and achievement. In reality though, one could claim that economic sustainability has historically received far more consideration than social and environmental aspects. This is also obvious in the literature. For example, Hardisty (2010) writes about how in the 1960s and 1970s the public started taking notice of how our way of life led to environmental impacts. This encouraged the growth of regulatory powers and the industry "…began to see tangible evidence that the days of uncontrolled and unmonitored discharge of waste and effluents were beginning to end." (Hardisty, 2010, p.18). Numerous historical examples of industrial accidents exist (e.g. Exxon Valdez, Bhopal, Seveso, Deepwater Horizon), that demonstrate significant impact both environmentally and socially. Therefore, modern notions of SD seem to strive to even out the shift in focus among the three dimensions of sustainability, i.e. bring more attention to the social and environmental aspects.

The management of an organisation has a responsibility towards stakeholders to manage any risks that may threaten the company goals and stakeholder interests (Johansson, 2002a). As such, one might argue that risk management inherently provides qualities of a sustainable nature. For instance, Grant (2010) makes a comparison between fire protection (which is a means for managing risk) and environmental sustainability. He argues that the two share the common goal of making the world a better place, since "fire protection strives to preserve and maintain." (Grant, 2010, p.6). Risk reducing measures, such as fire protection, may entail significant capital investment which is not always easily advocated since there is much difficulty to show a positive return on investment. A situation where the risk reducing (fire protection) measure is not required in order to meet the requirements of the applicable building code, may also contribute to making the investment decision difficult (Johansson, 2002b). Furthermore, the purpose of risk reducing measures may paradoxically mask the benefits of the investment; as the risk reducing measures strive to minimize the occurrence of disturbances, they also limit the explicit indicators of their own performance. For example, if a fire never occurs, which is one of the purposes of risk reducing measures, one will never really see the actual benefit of the measure because one cannot be certain whether the fire did not occur due to the risk reducing measure or not. However, even though the benefits from risk reducing measures such as a sprinkler system may be hard to quantify, one can easily imagine those benefits if a fire incident actually were to occur. For instance, a sprinkler system, when activated, may prevent a fire from growing further or even reduce its size, this in turn likely means less environmental impact from airborne particles or polluted extinguishing water contaminating the surrounding area. If the fire is limited the following business disruption is likely to be limited as well, with less economic impact on the company and maybe no need to lay off employees (social benefit). Thus, there are clear links between risk management, fire protection measures, and sustainability.

Recent research by Jiangtao and Pin (2010) indicate that inclusion of sustainability factors (primarily environmental data) into the investment decision process might provide additional incentives to choose a certain investment option instead of another option where environmental data is not included. Implying that this is true, the willingness to accept a certain investment might increase if sustainability factors are included in the investment appraisal process. Therefore, it is interesting to investigate whether there is a need to develop further investment methods which includes additional assessment criteria to represent the benefits in a wider perspective; more specifically, a sustainability perspective. Stemming from this, a project has been initiated to investigate the need for, and present an example of, an extended investment assessment model that accounts for the positive impact that fire protection measures might have on sustainability.

1.2 Purpose and objectives

1.2.1 Purpose

The purpose of the thesis is to investigate how the emerging knowledge of sustainability can be included in decision-aiding methods aimed at assessing investment in risk management measures.

1.2.2 Objectives

The purpose of the thesis is broken down into the follow set of objectives:

1. Investigate how the modern interpretation of sustainable development affects traditional investment assessment with regard to fire protection measures.

    a. How has the rising popularity of sustainability changed the general appreciation of the risk profile in industrial companies?

    b. How is the assessment of investment in fire protection measures being performed today (traditionally)?

    c. In what ways are there needs to adjust the current methods for investment assessment to better account for sustainability?

2. Development of an extended investment assessment model.

    a. If applicable, how can the changing risk profile appreciation, in regards to sustainability, be incorporated into investment assessment for fire protection measures?

1.3 Delimitations

The project forms the master's thesis for a student at Lund University. The project must therefore be limited in scope so that it does not overly exceed the prescribed 800 working hours or any additional requirements of the master course. Therefore a number of general delimitations apply:

- The thesis focuses on a corporate perspective, even though a somewhat wider notion is also discussed.

- The thesis is aimed at investigating sustainability from a risk management perspective.

The extended model for assessment of investment developed in Chapter 6 includes a number of specific delimitation according to the following:

- The model is developed on the basis of consequence-limiting fire protection measures. Thus the model might not be applicable for probability-limiting measures.

- The model is of a semi-quantitative nature. i.e. it uses quantitative scores to assess qualitative properties.

- The model is of a non-monetary nature. Therefore, the resulting assessment will not give any information on what a particular investment is valued in monetary terms. The end user must decide on how to price a certain sustainability benefit.

- The model uses an ordinal assessment scale, thus not giving any information on how much better one investment option is compared to another. The model will however provide information of how the different alternatives are ranked compared to each other.

1.4 Method

The aim of a master's thesis, just as with research in general, is to provide new knowledge. Paulsson (1999) divides scientific knowledge into two categories; everyday research and paradigm shift. The latter is something that would fundamentally change the way we interpret something in our surroundings, and is quite rarely seen. The former category however, is what a master's thesis might be about. Paulsson means that academic knowledge of this type is characterised by its cumulative nature. i.e. the following features can be expected in academic research studies:

- The study shows that the author is familiar with existing knowledge in terms of theories, models, and data.
- The study as far as possible considers the existing knowledge.
- The study connects to, adds to, and deepens the existing knowledge.

Furthermore, academic knowledge is also characterised by being of general interest. From here on the research spans across several levels including a general research problem, a specific research question, and the actual study. An important consideration in academic research is that the actual study performed must be associated and connected to the general research problem, to ensure that the research does in fact add to the existing knowledge in a desired manner. (Paulsson, 1999)

1.4.1 Choosing suitable methods

In order to fulfil the expectancies of an academic research report one must perform the work according to well known, generally accepted methods. Keywords in the process of choosing a suitable method are that the work should be controllable, repeatable, and independent (Paulsson, 1999). Höst, Regnell, and Runesson (2006) note that the choice of method depends on the nature of the purposes and objectives set out for the project. Research theses might be of the following types:

- **Descriptive**, aims to find out and describe how something works.
- **Exploratory**, aims to determine how something works or is performed in detail.
- **Explanatory**, investigates causality and explanations of how something works or is performed.
- **Problem solving**, aims to find a solution for an identified problem.

By using several different methods one might acquire a better picture of the research problem. Subsequently, the method is actualised by the use of certain tools to gather the required information. Such tools can be interviews, questionnaires, observations, or literature reviews (Höst et al., 2006).

Other key notions in method discussions include the following (Paulsson, 1999, p.48, author's translation):

- **Validity**, represents to what extent one is measuring what was actually intended to be measured.
- **Reliability**, represents to what degree one would receive the same results if repeating the same measuring.
- **Objectivity**, represents to what extent the study is affected by values and opinions.

The chosen method should strive to maximise validity, reliability, and objectivity simultaneously. However, in choosing a suitable method it is important to consider the available resources. Paulsson (1999) suggests that one should ask the questions: What is possible? Among the possibilities, which is the most efficient? And finally: What types of results are desirable? He further mentions the importance of clearly motivated choices of methods.

Based on the above, the subsequent section summarises which combination of methods are used in this particular thesis.

1.4.2 Methods used in this thesis

The thesis in this report consists of three primary parts:

I. Identifying key notions in the fields of risk management, sustainability and investment assessment, as well as investigating their correlation.
II. Development of an extended model for investment assessment.
III. Evaluate the developed extended model for investment assessment

The extent of each of the above parts declines in the same order as presented. i.e. the biggest effort in spent on part I, thereafter part II is less extensive in terms of work load and finally part III is made mostly at an indicative level.

Part I

The first part of the thesis is mainly of a descriptive and explanatory nature. In order to provide a connection to the existing knowledge and to get acquainted with the relevant terms, a primary focus is put on a relatively extensive literature review. Based on the literature review of the core theoretical aspects of risk and risk management (including fire protection), the sustainability concept, and investment assessment, part I is intended to show how these three segments interrelate with each other. Part I essentially serves to fulfil thesis objective one (1) described in section 1.2 above.

The literature review is an essential requirement to investigate the existing knowledge on the subjects. Although, as the thesis proceeds, an option might be to include interviews or questionnaire studies among business leaders for example, to learn the corporate perspective of risk management, sustainability, and investment assessment. In fact during the thesis work inclusion of interviews was considered. However, due to the available resources an emphasis on the literature review was continued. The literature searches were performed in electronic databases such as LOVISA (Lund University library catalogue), ELIN@Lund (Electronic Library Information Navigator, at Lund University), Web of science, Web of knowledge, CRCnetBASE, Springer Link, and KTH Library catalogue.

Literature review is a good tool for gathering information on a general level. Objectivity, in terms of reduction of the thesis author's values and opinions, is ensured via the use of several different external authors located via searches in different literature databases. On the other hand, going into specific research questions, and investigating specific areas of application, the literature might provide limited information.

The chosen method for the first part of the thesis is considered to provide reasonable levels of reliability and validity. The former might to some extent be questionable, since the use and combination of key words could result in somewhat different search results.

Part II

The development of a model is of a problem solving nature. i.e. the information gathered under part I is used to assemble a model to “solve” some of the problems that are expected to occur. However, this type of research normally uses less traditional methodologies, but is instead focused on a design research methodology. A deeper discussion on what this entails is presented in Chapter 6. Worth mentioning here is that continuous discussions (or deep interviews) are used during the entire development process. The “interviewees“ are Tobias Ekberg, Group Manager – Field Engineering, at FM Global, and Lars Stenblom, Vice President – Risk and Insurance, at Trelleborg AB.

Validity and reliability of the development phase is handled in the discussion on the design process presented in Chapter 6. Reasonable levels of objectivity are accomplished via input from external personnel.

Part III

The last part of the thesis is a brief evaluation of the developed extended model for investment assessment. For performing an evaluation, several methods can be employed. Examples include interviews, questionnaires, and case studies. Given that the evaluation is of a limited character, interviews or case studies might be the most valid and reliable methods. However, as part of efficient resource management, a written questionnaire is chosen instead. In this way the evaluation is effectively self-driven once a questionnaire has been put together (except for when it is time to collate the results). Compared to both interviews and case studies the validity might be reduced by using a questionnaire study. This is however considered acceptable given the large time saving that the questionnaire study implies. A detailed description of the model evaluation and its results is presented in Chapter 7.

Part II and III together essentially serve to fulfil thesis objective two (2) described in section 1.2 above.

1.4.3 Outline

Figure 3 below shows the thesis outline on chapter level. As can be noted, Chapters 2, 3, and 4 are documented as parallel sections before they are combined in Chapter 5.

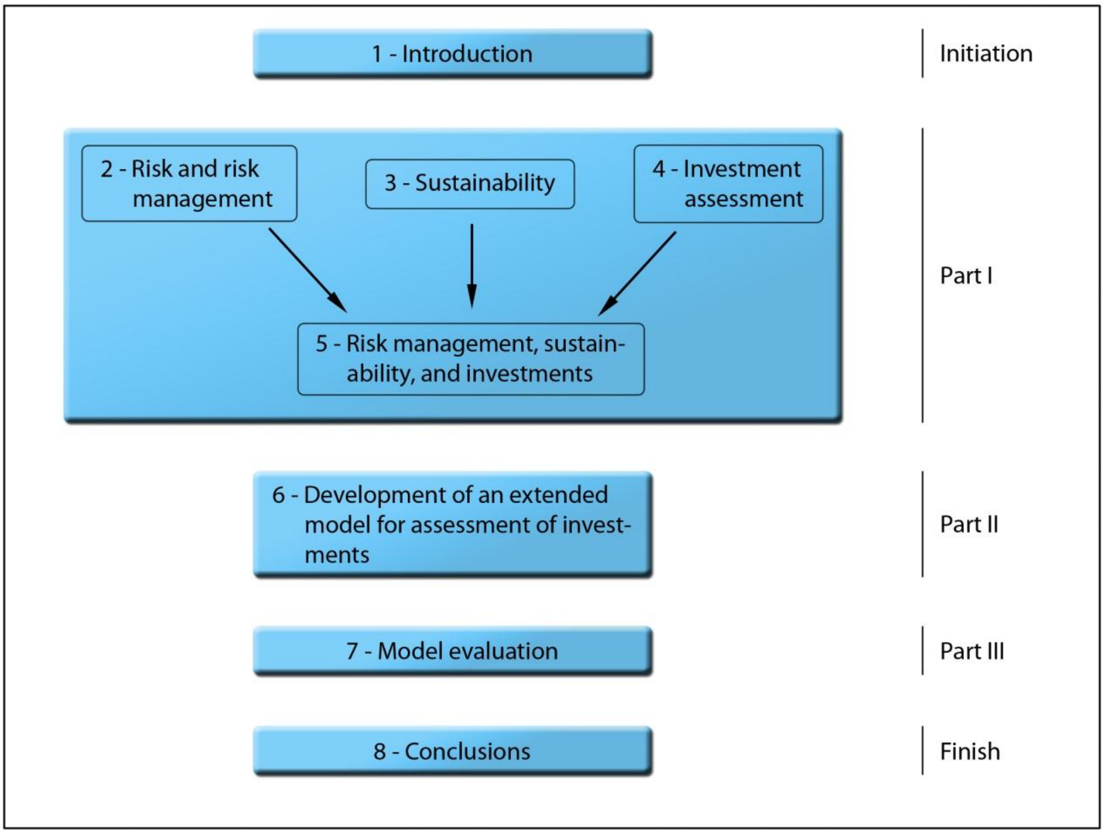


Figure 3: Chapter outline.

Chapter 2 – Risk and risk management

This chapter serves to discuss and outline the principles of risk and risk management both in general terms and in a corporate perspective. In section 2.4 fire protection measures are introduced, and its links to risk management are discussed.

2.1 Risk by definition

Risk is a word of many meanings. It may be used in everyday speech without any particular consideration of the actual definition of the term. But in a professional situation on the other hand, perhaps as a core principle guiding the work of a risk manager, the meaning of the term could be extremely important to his or hers achievements. As Renn (1998) states, there is no commonly accepted definition of risk. This means that when talking about risks, there is a *risk* that people are referring to different understandings of the term. This last sentence by itself demonstrates an everyday use of the word risk, perhaps by poor language usage, but indeed making a valid point. Paulsson (2007) mentions that the word risk is commonly understood as for example, a probability, a threat or danger, a probability, or the combined assessment of the probability of the threat or danger occurring and the severity of the consequences from that same event. In many cases one might talk about risk and chance as similar concepts but with a significant difference in tonal meaning. For instance, when buying a lottery ticket you have the chance of winning a certain prize, perhaps one million dollars, but you also risk losing the money you spent on the ticket. In this situation, presuming that the lottery ticket price is cheap in relation to the prize money, most people probably do not consider buying the lottery ticket as a risky activity. But if we change the stakes the buyers' attitudes likely change too. For example, if the game means you have to bet your own car and the prize if you win is another car besides your own, and where the chance of winning or risk of losing is 50 percent, then participation in the game might be considered a significant risk. How people act in situations like this has to do with risk perception and risk aversion, but the example also indicates some form of general appreciation of the term risk.

As a general meaning, risk seems to more or less always refer to something unwanted, or at least potentially unwanted. In this context the term risk will be further discussed as being associated with the possibility that an event, due to natural causes or human activity, may lead to consequences with adverse effects. From a similar standpoint Renn (1998) defines risk as:

> the possibility that human actions or events lead to consequences that have an impact on what humans value. (p.51)

Note that Renn in his definition does not include any thoughts on adverse effects, but only that the potential consequences should have an impact on something that the affected person or group find valuable. This basically comes from the fact that it might be difficult to define what the meaning of adverse effects is, but also from Renn's beliefs that some risks might be desirable. As an example he refers to sport activities where people might strive to experience a certain thrill from taking risks. In such a perspective it might be interesting to discuss whether risk is a real existing phenomenon, or something that society has created?

In a technical point of view risk is often, though not by any means always, characterized as having measurable probabilities and consequences. As such, risk is considered an objective feature. However, social scientists do not agree and instead argue that risk is inherently subjective. Slovic (2001) discusses the notion further and means that from this point of view, risk does not exist, waiting to be measured, but rather is a social construction created by humans as a help to deal with uncertainties and dangers in life. Even though the dangers from nuclear or chemical accidents are real, their risks are not real and objective, since they are all modelled with tools filled with subjective and value-laden assumptions (Slovic, 2001). However, as risk deals with *potential* of *real* consequences, one might similar to Renn (1998) say that the risk concept is a combination of a subjective social construction and an objective representation of reality, even if the latter in a professional context is sometimes based on qualified assumptions.

Kaplan and Garrick (1981) also discuss the subjectivity of risk. They refer to it as the relativity of risk, meaning that risk is relative to the observer and, important to remember, also the knowledge available to the observer. An example of theirs is that if there is a hole in the road around the next corner, the hole poses a lesser risk to a driver that knows about the hole beforehand, compared to the risk it poses to a driver that do not know about the hole. This also leads into the distinction between risk and uncertainty. The two terms are often seen together, possibly because risk on many occasions refer to future happenings and the future is inherently uncertain to predict, but uncertainty could very well exist without risk. You could be uncertain of a phone number without being exposed to risk for not completely knowing the number. Former US Secretary of Defence Donald Rumsfeld once made a thoughtful statement about uncertainties:

> Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns - the ones we don't know we don't know. (Ezard, 2003)

Even though this statement does not directly refer to any links between uncertainty and risk, it shows in a thoughtful manner the core importance of understanding the basics of uncertainties. In a risk context, both knowledge, in terms of information, and appreciation of uncertainties are key factors to the process of handling risk situations. In order to practise risk management it might therefore also be necessary to familiarize with a definition of risk that is more quantitative than what has been discussed above.

2.1.1 A thought of triplets

Kaplan and Garrick (1981) writes about the need for a clear and quantitative way of expressing risk, in order to allow for properly weighing of options in rational decision-making. On the basis of this statement, Kaplan and Garrick developed a risk definition that emanates from the following three questions:

1. What can happen?
2. How likely is it that it will happen?
3. If it does happen, what are the consequences?

The answers to these questions are compiled into a scenario and referred to as a 'triplet' on the following form:

$$< s_i ; p_i ; x_i >$$

Where:
s_i is the scenario description;
p_i is the probability of that scenario; and
x_i is the consequence for that scenario.

By including all imaginable triplets to the same analyzed situation, a risk (R) for that situation appears as a set of answers on the form ({} denotes a set):

$$R = \{< s_i ; p_i ; x_i >\} \qquad i = 1, 2, \ldots, n$$

For a specific situation (for example building of a chemical processing plant) there might exist a number of scenarios, each having a number of combinations of probability and consequence. Therefore, one might say that the entire risk associated with the particular situation, expressed as *R*, can be divided into categories in accordance with the different scenarios (s_i) constituting it. In that way, the result is one risk expression for each scenario, which together with all the other scenarios builds up to a total risk for the entire system studied.

The probability (p_i) usually is a number that can be obtained from reviewing statistics from previous events. Kaplan (1997) defines three formats that the probability can be expressed in; it can be expressed as a one-time probability, a frequency for repeating events, or as a probability of a frequency. If the frequency or probabilities are uncertain, it can be useful to assign a distribution curve to the probability term. A similar approach is suitable for the consequence (x_i). One can certainly turn to statistical measurements even for the consequence, but to get a more general and broad result other denotations are required. Consequences are often some form of damage, such as injuries or deaths, property damage, legal repercussions, lost productivity and income due to restoration time, lost market shares, bad publicity etc. Finding the relevant consequence is likely embedded with uncertainty as well. The probability for the negative event to occur is one thing, the probability for the event to lead to a certain degree of consequence is another. Just like for the probability term (p_i) a practical way of dealing with uncertainty of this type is to assign a distribution curve to the size of the consequence (Kaplan, 1997).

A common way of quantifying risk is to simply multiply the probability for a scenario with its consequence. However, as Kaplan and Garrick (1981) states, this is not a good representation of the actual risk. For one thing, such mathematical operations do not consider the independent meaning of probability and consequence respectively. That is, a high probability event with a low consequence might have the same calculated risk as a low probability event with high consequence. In a case like this it could be hard to distinguish between risks that clearly are not similar even though their quantitative risk value is the same. Similarly, doing the equivalent mathematical operation to the cumulative risk expressed as *R* above, effectively resamples the risk as being the mean of all triplets instead of all triplets as a whole. To clarify, according to Kaplan and Garrick (1981), the interpretation of the risk for a certain event (scenario) is the total appreciation of all triplets for that scenario, containing several paired probabilities and consequences. In other words, the risk is neither a number, nor a curve, but a complete set of triplets for a complete set of scenarios (Kaplan, 1997). The risk can however be illustrated as a curve by plotting all triplets for a scenario into a graph, using cumulative probabilities and ordering the scenarios by falling consequence. Such operation results in a presentation of risk similar to the frequency-number curve (FN-curve). The FN-curve is normally used to illustrate the collective risk (societal risk) from a certain risk source and shows on the vertical axis the accumulated frequency of accidents, and on the horizontal axis the number of fatalities. This type of risk-illustration is not of any further interest to this report.

2.1.2 The inevitability of risk

"we are not able in life to avoid risk, but only to choose between risks". With those introductory words on the quantitative definition of risk described above, Kaplan and Garrick (1981, p.11) neatly pinpoint the inevitability of risk. Judging from the above discussion on how to define risk, it is apparent that risk is something we all experience in one way or another on an everyday basis. In most cases the everyday risks are minor and not really noted at all, in other cases they can be more serious and require attention. Examples entail the risk implied by crossing a street, buying a lottery ticket, not using seatbelts in the car, riding a bike without a helmet etc. Eliminating all risks is virtually impossible, and can be extremely costly (Paulsson, 2007). An ideal risk analysis attempts to include all imaginable risks (a complete set of scenarios), but since this might be difficult both due to uncertainties and due to practicalities, one should at least include the most important ones (Kaplan, 1997). Paulsson (2007) refers to a widely discussed "90-10 principle" which in essence means that 90 percent of the money has to be spent on eliminating the last 10 percent of the risks. He further mentions that due to irrationality and lack of knowledge, a lot of money is spent on regulations that have limited effects. This implies that risk management can indeed be a costly practice, but more importantly it can also be, and to a great extent is, a means of reducing unwanted costs. Therefore, sound risk management can be a greatly beneficial management tool on several levels in the society as well as in corporate organizations.

2.2 Risk management in general

Risk management is all about identifying potentially harmful events and, when considered necessary, taking relevant action to control the risks they impose. It seems to be a straight forward process, but as was seen above, the concept of risk includes several uncertain features that might be difficult to approach directly. How can it be determined which events are harmful? When do we need to mitigate a risk and when can we let it pass as insignificant or acceptable? What actions should we take if the risk is considered unacceptable? These, and many more, are all important questions in regard to risk management, and to deal with them a well-structured procedure is required. The International Electrotechnical Commission (IEC) has developed a standard for risk analysis in technological systems (IEC, 1995) in which a model for the risk management process is presented. The model, shown in Figure 4, illustrates in a clear way an example of the fundamental parts that constitute the risk management process. As can be seen in the figure, risk management is a combination of risk assessment and risk control, where risk assessment is a combination of risk analysis and risk evaluation. These three main parts of risk management are further described in sections 2.2.1 through 2.2.3.

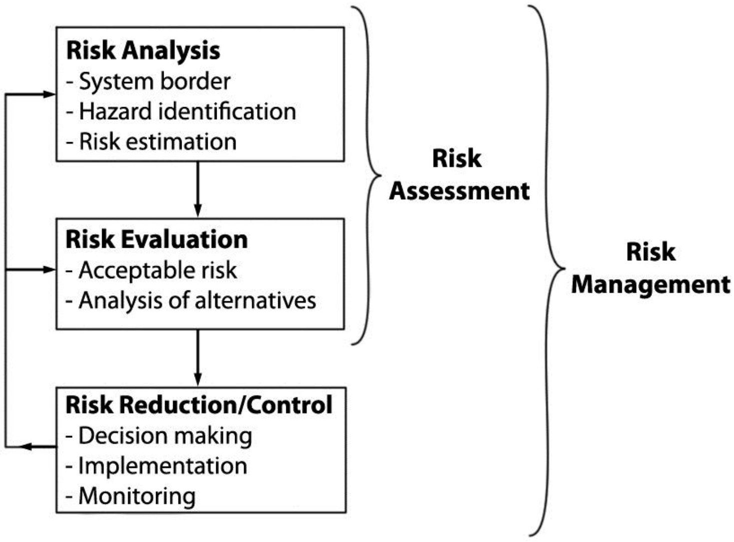


Figure 4: Risk management model, reproduced from IEC (1995, p.41).

2.2.1 Risk analysis

The risk analysis is the first step in the risk management process. In order to conduct a risk analysis one first needs to define what is to be analysed, i.e. determine the system border. This is followed by the hazard identification and risk estimation. When it comes to hazards it is important to point out that they are not the same as risks. As was seen above, Renn (1998) defined risk as the possibility that an event could impact something that humans value (refer page 25). A hazard could pose a threat to something humans value and might in such case be treated as a risk, but it could also be a threat without being a risk. For example, an electric cable on the floor could pose a tripping hazard to people, but if the cable is located in an area where no people are walking it probably does not constitute a risk for tripping. This is also commented on by Kaplan and Garrick (1981) in the way that a hazard by itself is simply a source, but combined with a likelihood it can become a risk (Kaplan & Garrick, 1981).

There are numerous methods for risk analysis. As shown in Figure 4, most risk analysis methods serve to identify potential hazards and provide risk estimation by combining probability and consequence for a hazardous event. Risk analysis methods are only briefly described in this report. It is however interesting to note the difference between quantitative and qualitative methods. Figure 5 shows several risk analysis methods and how they relate to each other on a scale from qualitative to quantitative in character.

Qualitative methods are completely non-numerical and are generally easy to work with as they are not overly detailed. Therefore they can be very useful in the initial stage of a risk analysis as a relatively quick way to identify areas where a more detailed analysis is needed. Since qualitative methods are often based on judgment, they might require involvement of personnel that are knowledgeable of the area or system that the analysis applies to. Table 1 shows a brief summary of a few qualitative methods.

Table 1: Brief description of some qualitative risk analysis methods.

Method	*Description*
HazOp	HazOp stands for *hazard and operability study* and is especially useful in analysis of process plants. The possible deviations of a set of parameters are examined for various locations in the process. It can for example be analysis of how a change in pressure or temperature in a gas pipeline affects the rest of the process.
What if?	This method is based on asking the question "What if this happens?" It is a simple model that easily overlooks important issues since it requires a degree of imagination (Paulsson, 2007).
Check lists	Check lists are effectively a control measure to ensure everything is in order relative to a predefined safety level. It is easy to interpret and compare but might miss important problems as it is based on historical events (Paulsson, 2007).
Risk matrixes	Risk matrixes combine some notion of the probability for an event with the consequences for the same. As a qualitative method the probabilities and consequences are given non-numerical notions of the type "Low; Medium; High" or similar. Matrixes can also be semi-quantitative and is then reinforced with numerical values of the probability and consequence.

Semi-quantitative methods basically combine numerical values with non-numerical values in the risk analysis. The values in a semi-quantitative analysis do not have to be exact, but rather show an order of magnitude for different alternatives to make it possible to order them relative to each other. Thus, the values must not necessarily be numbers, they could just as well be words as long as they provide ordering capabilities (for example Low; Medium; High). The scale is in this case of ordinal character, i.e. showing which item is higher than another without considering how much higher it is. For example, four on an ordinal scale is definitely higher than 2 but not necessary twice as high.

Quantitative methods in contrast, are much more detailed and time consuming to conduct. They are entirely based on numerical values for probabilities/frequencies and consequences that are inherently uncertain. As such, quantitative methods also require some form of handling of uncertainties, similar to that described in Kaplan and Garrick's quantitative definition of risk (refer section 2.1.1). This is normally dealt with by assigning distribution curves for the included parameters to obtain a conservative final result, i.e. to be on the safe side. Table 2 shows a brief summary of a few quantitative risk analysis methods.

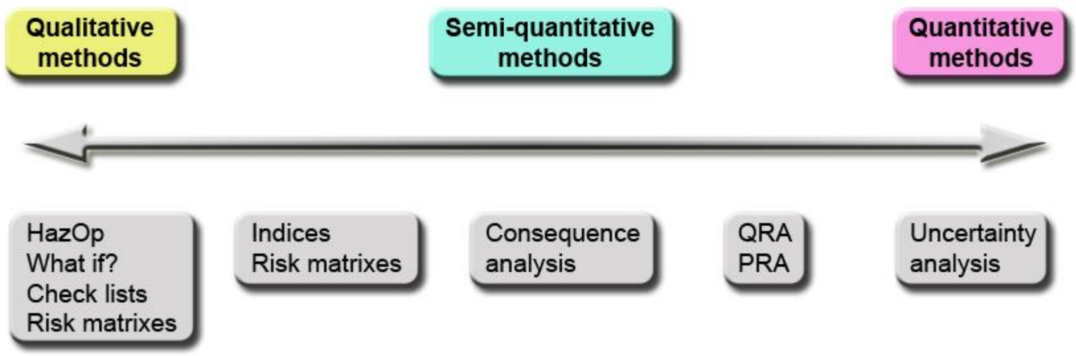


Figure 5: The qualitative/quantitative nature of different risk analysis methods. Reproduced from Nilsson (2003, p.20).

Even if a quantitative risk analysis is sometimes desirable, it may not always be possible to conduct. Difficulties can arise due to insufficient information about the system, lack of statistical data, or influences by human factors (IEC, 1995). Another noteworthy aspect is that the risk analysis must be suitable for a number of circumstances. For example, the analysis must be understandable and interpretable by management; the value of the analysis must exceed the cost of conducting it; and the uncertainties of the analysis must not exceed the acceptable limits (Paulsson, 2007). The latter also applies to risks in general, i.e. they must not exceed acceptable limits. Determining what is acceptable is however subject for debate. This is where the management process proceeds to the next step; risk evaluation.

Table 2: Brief description of some quantitative risk analysis methods.

Method	*Description*
QRA	QRA stands for *quantitative risk analysis* and there are well-recognized methods for conducting QRA using for example event tree analysis (ETA, examines a set of possible chain events emerging from a initiating event). In a QRA probability and consequence parameters are quantified and as such are inherently uncertain. Therefore QRA may also entail uncertainty analysis. QRAs are generally quite detailed and can thus also be time consuming and costly to conduct.
PRA	PRA stands for *probabilistic risk analysis* and is a method similar to QRA. The main differences are that the PRA generally is somewhat more detailed than the QRA and is more focused on event tree analysis and fault tree analysis (FTA, examines a set of possible events that occur prior to an unwanted event) (Nilsson, 2003).

2.2.2 Risk evaluation

While the risk analysis provides an identification of hazards and the corresponding risk estimation, it does not say anything about how to interpret the given risk. This is the purpose of the risk evaluation step. Here the risks are valued and if applicable different options are assessed in relation to each other. The primary challenge in this is to determine which risks are acceptable and which are not. Davidsson, Lindgren and Mett (1997) present four core principles on which they consider risk valuation should be based:

- **Fairness principle**. An activity should not impose risks that by reasonable measure could be avoided. This means that action to reduce or mitigate a risk shall be taken for all risks where it is technically and economically reasonable to do so, regardless of the size of the risk.
- **Proportionality principle**. The total risks imposed by an activity should not be disproportionately high in relation to the benefits (income, goods, services, etc.) generated by the activity.
- **Distribution principle**. Risks should be evenly distributed in the society in relation to the benefits provided by the risk generating activities. This means that no person should be exposed to a risk that is overly high in relation to the benefits the risk generating activity provides for the person in question.

- **Avoidance of disasters principle**. Risks should not generate consequences too large to be handled with available emergency resources.

Davidsson et al. base their four principles on two assumptions. First, people both in the industry and as part of the society are willing to accept certain activities even though they inevitably generate some level of risk. Second, there are finite resources for mitigating risks in the society. Especially due to the latter it is important to note that risk valuation on a societal level should allow for continuous improvement of the safety level, be practicably implementable, and contribute to a cost effective utilization of risk reducing measures. In terms of costs, it is in practise probably not possible to adhere to all four principles simultaneously. This means that avoidance of disasters may require resources that would generate a significantly greater risk reduction if the same resources were spent on reducing more common accidents with lesser consequences (Davidsson et al., 1997).

The topic of risk valuation is widely debated, and as one can imagine the opinions are diverse. A principle that is adopted in many European countries is to compare the risks generated by a certain activity against some predefined guidelines on acceptable or tolerable risk (Davidsson et al., 1997). However, a fundamental question is if it is at all possible to determine such guidelines? Some people might argue that there is no such thing as "acceptable risk". Still, on a societal level, a number of risks exist that effectively seem to be considered acceptable, which is exactly what Davidsson et al. used as a base for their four principles above. Driving a car is for example associated with risk, but is generally considered acceptable. Though the reason it is considered acceptable is probably because a lot of effort has been devoted to make our roads a reasonably safe place to drive. As such, one could say that at least in traffic some predefined level of acceptable risk does exist, even though it is not explicitly spoken about. The same probably applies to many industrial activities. In Sweden there is currently no specified quantitative level of acceptable risk. However, internationally such limits exist in, for example, the Netherlands, Great Britain, Australia and Canada. A common approach when using specific risk limits is to derive an upper and lower limit in terms of the magnitude of the acceptable and unacceptable risk. In reality there is not really a lower limit to what can be considered acceptable, so one can rather talk about two upper limits; one constituting the limit below which risks are acceptable, the other constituting a limit above which no risks are accepted whatsoever. Figure 6 describes the two limits separated by the so called ALARP-region. Risks in the ALARP-region must be reduced to *as low as reasonably practicable* (ALARP).

Using the concept of the ALARP-region seems like a fair approach for risk evaluation. However, one should keep in mind that using "reasonably practicable" as a criterion inevitably entails a degree of subjectivity. Cost-benefit analysis (CBA) is becoming more popular in decision making regarding risks located in the ALARP-region. However, Kletz (ref 7.11 in Davidsson et al., 1997) points out two arguments against the use of cost-benefit analysis in such an application; First, the moral argument is that we may accept a risk if it is so small that it is virtually insignificant in relation to other risks, but we cannot accept a risk just because it is expensive to reduce. Second, the pragmatic argument is that there might be a tendency to "get away with" risks by claiming they are too expensive to reduce. If risk reduction on the other hand is an absolute requirement the risks most often can be dealt with in some way.

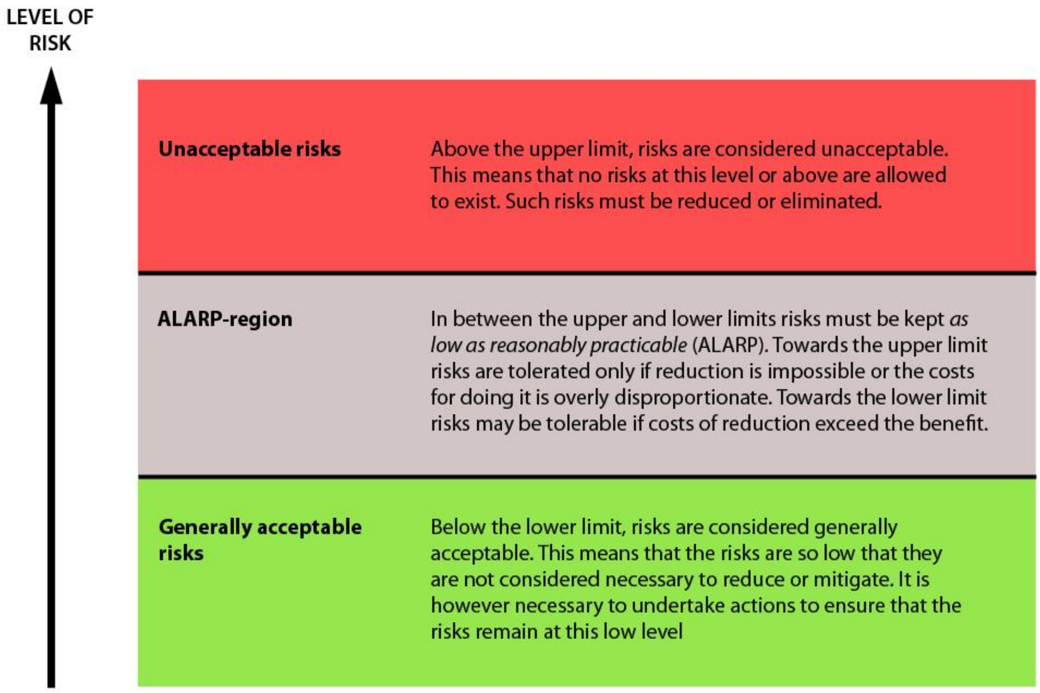


Figure 6: Concept of upper and lower limits for acceptable/unacceptable risks, with the ALARP-region in between (Davidsson et al., 1997).

An interesting question that arises when discussing the acceptability of risks is to whom the risk is acceptable? As a matter of fact, the valuation of risk is influenced by the knowledge about both the activity generating the risk and the risk itself. Therefore the risk valuation can easily be affected by temporary publicity or insufficient information. Likewise, is the risk valuation dependent upon whether the person making the valuation is affected by the risk or not (Davidsson et al., 1997). In the latter case one can distinguish a difference between people as individuals and people as members of the society; a person might consider a risk acceptable to the society as long as the risk is carried by someone other than the person themselves. A similar occurrence can be seen in market economic situations; a person might believe that donating 1 percent of the gross domestic product (GDP) to foreign aid is a good thing for the country to do, but might be reluctant to give up 1 percent of his or hers personal income for the same purpose (Mattson, 2004).

Deciding who has the right to determine which risks are acceptable or not is yet another hot topic in the risk management debate. Should public perception of risks influence the guiding principles for risk management? Should risk reduction resources be prioritized by recommendation from technical risk assessments or from the public risk perception? Renn (1998) writes about this. Two main risk camps exist. One side, primarily those who believe that risk is a social construction, claim that since it is the people who are at potential harm from risk-generating activities, they should have the privileges to decide what an acceptable level of risk is. The other side, primarily those who are technical experts, claim that the public perceptions of risk may easily be misguided by press coverage and intuitive biases (Renn, 1998). It probably cannot be decided on what is right or wrong in this debate, although it does have an important role for the purpose of risk management. Discussions of this type are to a great extent of political interest as well, especially when it comes to deciding what measures to take against which risks.

2.2.3 Risk reduction/control

The last step in the risk management process is to determine how to reduce or control the risks that have been identified and evaluated in the previous steps. Kaplan and Garrick (1981, p.12) wrote: "Risk is never zero, but it can be small", and on a general basis the purpose with risk control is to make the risks as small as possible. Some basic approaches to risk control are:

- **Acceptance**. Some risks can be considered acceptable. It can be that the risk is so small that it is not necessary to pay any further attention to. It can also be that the risk is practically impossible to mitigate or that the cost for doing so exceeds the benefit from the risk mitigation. Of course, from a societal perspective determination of acceptable risks must be done with caution.

- **Avoidance**. In some cases the risk can be completely eliminated by simply changing or taking out the activity that generates the risk. However, eliminating a risk is nearly impossible and changing the activity will likely introduce other risks.

- **Reduction**. Although it might be difficult to eliminate a risk, it is often possible to reduce it. Reduction of risk can be focused either on reducing the *probability* for an unwanted event to occur, or reducing the *consequence* of an event that does occur. In many risk situations, reduction of the probability can be a difficult achievement. In such case an easier task might be to reduce the potential consequences. This can for instance be separation of highly flammable goods from potential ignition sources. In an example like this, the main risk reduction is achieved not by reducing the probability for a fire to occur, but rather reducing the probability for a fire to quickly grow out of control and render large consequences.

- **Sharing**. The most obvious form of risk sharing is insurance coverage. Almost all physical activities in our society are to some extent linked to insurance. It is effectively a means of risk distribution. That is, if a negative event was to occur the insurance company would pay for some of the damages exceeding the deductible amount, hence from an economic perspective the risk has been shared. However, for a risk to be insurable it must be well defined and easy to identify (Paulsson, 2007). Thus, there are many important features not least in corporate organisations that are difficult, if not impossible, to protect with insurance coverage (e.g. reputation, trademark, market share etc.).

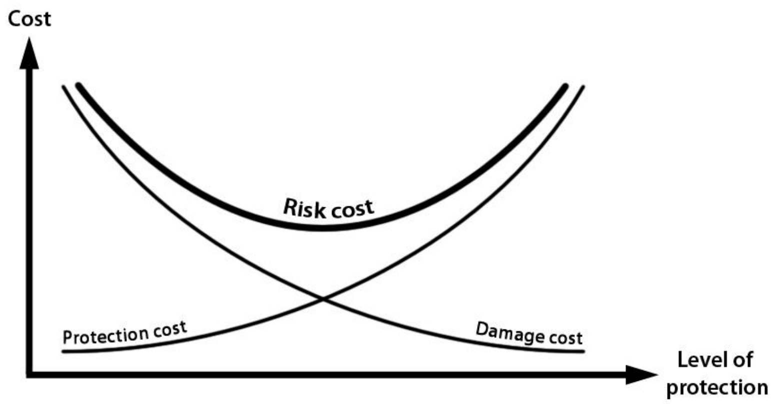


Figure 7: The relation between protection cost and damage cost. Reproduced from Nystedt (2000).

As was discussed in section 2.1.2, all risks cannot be reduced or eliminated. Achieving a risk that is zero would simply be too costly. Nystedt (2000) writes about the importance to balance risk and protection (risk reduction/control) in order to keep costs at a reasonable level. He talks about *risk cost* and refers to the total cost of risk management (risk management administration, insurance, etc.) and protection. From an economic point of view this can be very helpful. Basically a cost effective approach to protection is that the cost of protection should not exceed the cost of the expected damage corresponding to a certain level of protection. Figure 7 shows the relation between protection cost, damage cost, and the total risk cost. Although this might be somewhat generalising, and not always applicable, it shows and important relation between cost and benefit in risk management applications.

2.3 Corporate risk management

Conducting business activities is all about creating value for the relevant stakeholders. Inevitably, business activities also entail numerous risks. Just starting a business is a risk since it essentially means you are betting a lot of money on something you hope will grow, prosper, and generate a steady income for the foreseeable future. Along the way many decisions must be made even if they are indeed risky ones. In essence, corporate activity is risky, but risks in a corporate application are always related to opportunity in some way. Otherwise there would be no reason for the company to expose itself to risk (Paulsson, 2007). One of the most critical challenges though, is to determine how much risk an organisation is prepared to, and will, accept in the process of creating value; the organisation's *risk appetite* (Committee of Sponsoring Organizations of the Treadway Commission (COSO), 2004). This is what corporate risk management is; managing the risks that are deliberately taken in the process of business activities.

A well-recognized term associated with corporate risk management is *enterprise risk management*. COSO (2004) has developed an integrated framework to help organisations enhance their risk management procedures. Within the framework COSO defines enterprise risk management as:

> Enterprise risk management is a process, effected by an entity's board of directors, management and other personnel, applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and

> manage risk to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objectives. (COSO, 2004, p.2)

By this definition enterprise risk management is a method for the company to ensure that no unwanted events occur, or so that events that do occur do not overly affect the company objectives.

COSO intentionally made its definition broad in order for it to be applicable across organisations, industries, and sectors. At a fundamental level, enterprise risk management is no different from risk management in general. That is, all the steps included in the risk management process described in section 2.2 (Figure 4) are normally necessary to consider also in an enterprise risk management perspective. COSO chooses to interpret the risk management process by eight steps:

- internal environment (e.g. safety culture),
- objective setting (to identify what is important within the company),
- event identification (events affecting achievement of objectives),
- risk assessment,
- risk response,
- control activities (to ensure effective risk response),
- information and communication (within the entire company), and
- monitoring (with modifications as necessary).

In enterprise risk management these eight steps relate closely to the companies' overall business objectives, which according to COSO can be grouped in four categories: strategic, operations, reporting, and compliance. This approach may very well be less comprehensive and less structured in smaller companies where risk management is easier to grasp. As a whole, COSO's framework for enterprise risk management "helps an entity get to where it wants to go and avoid pitfalls and surprises along the way." (COSO, 2004, p.1).

2.3.1 Corporate risks

From a corporate perspective there are numerous risks that must be appreciated and analysed in order to ensure unwanted disruptions do not occur. The management of an organisation also has a responsibility towards its stakeholders to manage any risks that may threaten the organisation's goals (Johansson, 2002a). Doing this in a structured manner includes identifying all imaginable risks that may exist. Traditionally risk research has been focused on threats from natural hazards and fires to humans and property, but also financial risks have received some attention (Paulsson, 2007). The same applies to the corporate organisation's risk management. However, lately the appreciation of corporate risks is being widened, both in terms of hazards and consequences (Paulsson, 2007).

Intuitively one can imagine that economic risks are of great importance to corporate organisations. If a company does not perform adequately from an economic perspective, the very key drivers of the company are threatened. Because, to a great extent corporate organisations exist for the reason that there is an opportunity to make money (Drucker, 1999, in Möller & Schaltegger, 2005). Consequences in terms of property damage and injuries can lead to significantly increased costs. Such consequences may also lead to disruptions in the organisation's operations, which in turn could mean loss of income, loss of market shares, decreased stock index, damaged stakeholder relations etc. In line with modern technology, IT risks are also a growing field of concern and Paulsson (2007) notes that IT system disruptions longer than a week may lead to significant consequences like bankruptcy.

Environmental and social impacts from an organisation's activities may also lead to repercussions that are damaging to the organisation. Toxic contamination of air, soil, and water as well as health effects on human beings can lead to legal consequences both in terms of lawsuits or fines. This may also severely damage the organisation's trademarks and reputation. As an example of this Andersson (2005) brings up the Erin Brockovich case, where Pacific Gas & Electric (PG&E) contaminated the drinking water in a small American town called Hinkley. The consequences included health impacts and deaths due to cancer, kidney and liver diseases, and serious respiratory diseases. PG&E did not only have to pay an enormous settlement, but their reputation was also greatly affected by the fact that the incident was later made into a Hollywood movie.

Liabilities and boycotts are other fields of corporate risks. All organisations are subject to a number of liabilities, stemming from ownership of land and property, treatment of employees, manufacturing products, provision of services, and the like. Boycotts can be damaging to the organisation's reputation in a similar manner. (Andersson, 2005)

2.3.2 Supply chains

Some 150 years ago when agriculture was the primary economic unit, in most industrialized countries the societies were built around the local farms. Each farm was practically self-sustaining as most of the production and usage of goods took place at the farm in question. Most of the transports were between the fields and the farm, and storage was important for the survival of the inhabitants since food production, at least in Sweden, mainly took place in the summer while consumption was needed all year around. Today the situation is different. Now it is rarely one single company that develops a product from raw material directly to a finished end product. Rather, due to the modern globalisation, specialisation, and mass-production, groups of companies collaborate in completing the end products. These groups, or networks, of companies are also known as supply chains. Competition between companies has shifted into competition between different supply chains instead. The previously so important storing has also become an undesirable feature and now just-in-time deliveries are considered more efficient. (Paulsson, 2007)

Figure 8 shows a typical supply chain, where physical flows of material often exist from start to finish.

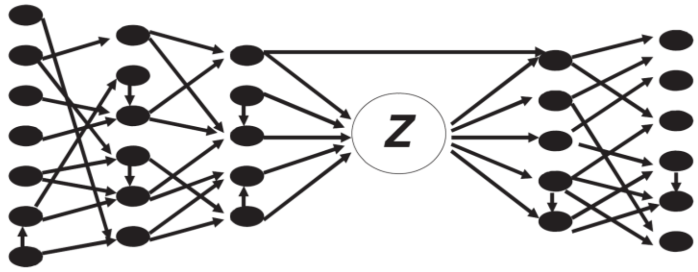


Figure 8: Typical supply chain network for company Z (Craighead, Blackhurst, Rungtusanatham & Handfield, 2007, p.135).

With extending global business networks comes increasing dependencies as well, and disruptions in one company can quickly spread to other companies within the supply chain (Paulsson, 2007). Thus, the development of complex supply chain networks leads to increasing exposure to risks (Christopher & Lee, 2004). In fact Craighead et al. (2007) argue that supply chain disruptions are unavoidable and that supply chains thus are inherently risky. One can easily imagine the devastating impact on the supply chains should one company suffer a major disturbance, such as for example a fire with severe property damages and down time due to recovery. Companies downstream may for example choose another supplier, and business relations may be weakened. The supply chain logic can also be highly relevant within an organisation in terms of internal dependencies. Disturbances in one unit may, depending on the structure of the organisation, very well generate disturbances in other units of the same organisation. Disturbances in a supply chain, whether it includes internal dependencies or not, may also lead to an escalating effect, where the impact is greater a few units away than in the unit where the event actually occurred (Paulsson, 2007). Therefore management of supply chain risks and internal dependencies is very important to the individual organisation. Furthermore, it is only the individual organisation that can take action to prevent disturbances in the supply chain (Paulsson, 2007).

Christopher and Lee (2004) note that confidence is of great importance within supply chains. They mean that *chaos effects* resulting from over-reaction, unnecessary interventions, mistrust, and distorted information, can be increased by the complexity and uncertainties of the supply chain. In their opinion these types of confidence deficiencies can collectively result in a higher risk exposure, and a supply chain with high risk exposure cannot perform efficiently. Developing information procedures within a supply chain can help reduce the risk of confidence risks, because "…'information enriched' supply chains perform significantly better than those that do not have access to information beyond their corporate boundaries." (Christopher & Lee, 2004, p.319). Craighead et al. (2007) similarly concludes that a supply chain disruption is less likely to be severe if there are capabilities to warn other entities in the supply chain in a timely manner.

In summary, the modern supply chains imply that unwanted events and disturbances can lead to both internal and external chain effects. Supply chain risks are thus of great importance from a corporate risk management perspective.

2.4 Fire protection and risk management

Fire protection measures are means of risk control, obviously aimed at reducing fire risks. The purpose of fire protection is to reduce damages and losses due to fire in terms of personnel safety, property protection, and also protection of the environment. As was noted above, fire risks are only a small portion of all risks in the society and in corporate settings. Fire however constitutes a static risk, which compared with many other risks is actually relatively easy to identify and mitigate against. Also, since this thesis investigates how the assessment procedure for investments in fire protection measures could be extended, it is of interest to briefly describe some types of fire protection measures.

Fire protection measures are normally categorized as active or passive systems. Active systems are systems, often electronic or mechanical, that actively detects a fire incident and in some way triggers a reaction. Active systems can be as simple as a battery powered smoke alarm which many people have in their homes. It can also be sophisticated electronic systems with interconnected smoke, heat, or flame detectors that provide detection coverage to a large facility, organised via a central control unit. From this unit a suitable reaction to the fire can be programmed. Examples of reactions are activation of an evacuation alarm, automatic closure of certain doors or hatches, activation of fire suppression systems, opening/activation of smoke ventilation, changes to normal ventilation flows, automatic alarm transmission to the local fire brigade, etc. Active systems can also be of mechanical nature such as for instance a traditional automatic sprinkler system (although some electronic components may be involved in the booster pump start-up) or a mechanically opened smoke ventilation hatch.

Passive systems on the other hand are static features that provide the same fire protection regardless of if a fire occurs or not. The typical example of passive fire protection is a fire wall or a specifically determined distance between two buildings. As an example, historically in larger cities firebreaks were created by building extra wide streets in strategic places to prevent an uncontrolled fire from spreading too far. Sometimes active and passive systems interact with each other. For example, a fire wall (passive system) in a building might have door openings in it. In such case the doors are likely to be provided with automatic door closers so that the door is always kept shut, thus maintaining the integrity of the wall. But if the doors for some reason must not be closed during normal operations, they can be fitted with magnetic devices that hold them open. These magnetic devices are then connected to the building fire alarm system so that if a fire is detected the magnetos release and the doors close (active system). This is probably one the most common interactions between active and passive systems.

Risk reducing measures in general can either be focused on reducing the probability for an unwanted event to occur, or focused on reducing the consequences of an event that does occur. Fire protection measures can be categorised similarly, even though most fire protection measures reduce the consequence of a fire. The probability reducing category probably rather refers to organisational measures such as management of hot works, separation of combustible materials from obvious ignition sources etc. These methods reduce the likelihood for a fire to occur. All other examples mentioned above are reducing the consequences of the fire, although in different ways; fire walls often prevent a fire from spreading outside a particular area in a building or block; an automatic fire alarm notifies the fire brigade who in turn can make efforts to reduce impact on humans, property, and the environment; an evacuation alarm notifies the building occupants so that they can exit the building before critical conditions occur; automatic sprinkler system prevents the fire from growing uninhibited and causing damage to humans, property, and the environment etc.

Among all the active and passive systems described above, only fire suppression systems are examples of systems that can actually prevent a fire from growing or even supress the fire. The automatic sprinkler system is the most commonly used form of fire suppression system. Therefore, the automatic sprinkler system constitutes an important and competent feature of industrial fire protection that is interesting to use as an example of fire protection measure in this thesis. As is shown in Chapter 5, fire protection in general, with the sprinkler system in particular, is closely related to sustainability as well.

Chapter 3 – Sustainability

Sustainability is a growing field of interest both in a global and a corporate perspective. This chapter is intended to inform the reader of what sustainability means; what it is, why we need it, and how we can use it to improve the situation for forthcoming generations.

3.1 *Why we need it*

From a sustainability perspective, some people believe and argue that the state of the world is in limbo. Others might say we worry for nothing. Regardless of where on the slope towards environmental and social meltdown we are located right now, and at what pace we are moving along that same slope, it is important to introduce some fundamental facts that underlie the sustainability concept. Debated around the world are many different arguments on the importance of changing our way of living. Although the opinions and proposed strategies may be many, two main purposes for employing a sustainable existence are prominent in the literature. First, there is urgency to deal with poverty and the increasing number of people in the world living under such conditions. Second, we must care for the natural capital (i.e. natural resources) that constitute the foundation of the ecosystems sustaining life on our planet (Hardisty, 2010). The order of presentation in this context does not imply that one objective is more important than the other. Rather, for the sake of understanding the primary drivers for sustainability thinking in a global perspective, these two objectives will be discussed as interconnected necessities, but without attention to their relative importance. The below sections outline a number of global trends of deteriorating conditions on our planet. The facts are intended to put perspective on the necessity to pursue sustainable development.

3.1.1 Population, poverty, food and water

We are many, and we continuously become more; the world population is growing at an inexorable rate. The United Nations' Population Project predicts that the world population over the next 50 years will increase from the current 6 billion to almost 10 billion. Roughly 40 percent of this increase is estimated to occur in the world's poorest regions, where the majority of the people already live in execrable conditions. In 2000 around 40 percent of the global wealth was owned by 1 percent of the population. Turned around this meant that at the time, half of the world's population owned less than 1 percent of the total wealth. Despite that, more and more people are living in poverty, with some economic indicators providing misleading information of an opposite trend. Between 1987 and 2004 the global average gross domestic product (GDP) per capita rose some 27 percent. However, as you can imagine, only relatively few experienced this increase in personal wealth. This witnesses that the world prosperity is significantly unevenly distributed. (Hardisty, 2010)

Poverty also means that there is likely a shortage of food. In fact, given the crucial importance of nutrients, lack of food might be the most critical factor of poverty. Medical care might be another, but as long as there is not enough food to survive, there is little reason to talk about health care. Of course there is also a critical need for water to survive, but since food production in most cases is dependent on the existence of water, the need for food and water go hand in hand. According to Hardisty (2010) food productions make up about 90 percent of the total use of fresh water around the world (Anderson (2005) states 70 percent). Similar to the food shortage, in many poor areas there is also a shortage of water. It might for instance be the desert-like regions in Africa or the dry lands in the Middle East. As the population increases in these areas the available fresh water per person will decrease, which in turn may lead to over-exploitation of the available water resources. An obvious effect from this is that food production capabilities are reduced even further.

By a quick glance at the history of civilization, it is clear that societies grew in areas which were rich on water. But as the population grew the need for agriculture did too. In order to expand the land use mankind had to start collecting and transporting water to the places where it was needed, or wanted. In fact, this way of handling water has effectively reshaped the natural hydrology in many parts of the world. Today, only about 3 percent of all the water on our planet is fresh, and only a third of this is available to the ecosystems. Desalination plants shaped by the modern technology provide important production of fresh water in some of the world's driest regions. Ironically though, the plants are in many cases powered by fossil fuels like oil and coal, which produce greenhouse gases and continue to increase our carbon foot print as they are burnt. As is commonly debated, burning of fossil fuels is increasing the global warming that drive droughts and further reduces the fresh water available in dry regions. Not only poor regions of the world experience increasing shortages of fresh water. The same is for instance happening in Australia and the United States, developed western countries that happen to have areas with limited fresh water resources. Pollution of fresh water is another common trend in many places in the world. Aside from being a prominently water consumptive practise, agriculture has also long been contaminating water with nitrogen compounds from fertilizers used to increase the productiveness of the earth. Obviously the industry has also contributed to pollution of fresh water. An example is large ground surface oil spills around the Middle Eastern petroleum production, which poses a significant threat to the sub surface fresh water aquifers. (Hardisty, 2010)

Food is not only about land use and fresh water consumption. Meat and fish are also common ingredients in our food intake. Especially when it comes to fish, the trends are alarming. A study published in 2003 showed that over the last 50 years (from 2003) the populations of large predatory fishes have been reduced by 90 percent (Anderson, 2005). Modern technology like sonar and satellite positioning have made industrial fishery overly damaging to the natural fish stock. With these types of fish finding measures it is easy for fishermen to find large quantities of fish and ensure a steady income. Some time ago the situation was drastically different. The old unsophisticated fishing equipment made it harder to find fish which meant that the stock was given opportunity to recap between swoops. As Anderson (2005) states, the modern fishing industry is eventually "a self-defeating practice, as the fleets run out of new areas to fish."(p.22). This is a clear example of how modern technology and new methods to produce more food entail activities that are unsustainable. If we use more of a resource than is replaced, the usage is unsustainable. For instance, if we use more fish or more fresh water than is replaced, eventually we will run out of fish and water, and thus this type of usage is unsustainable. Today changes in the fishing industry are slowly starting to show. For example, in Swedish grocery stores (and most likely in other places around the world as well) fish products labelled with a 'MSC'-marking are starting to appear. MSC stands for Marine Stewardship Council and the 'MSC'-marking is a fishery certification symbol. To obtain the marking the product must come from fisheries that are well managed in a way that preserves the ecosystem (Anderson, 2005). If this attempt to slow down the reduction of global fish stocks is an effective measure or not, will not be further analysed in this report. Some people do not believe in sustainability actions of this kind, but rather think it is a way of making unsustainable activities a legitimate development (Anderson, 2005).

3.1.2 Natural capital and Climate change

In the context of this report natural capital basically refers to the natural resources available on our planet. On the most fundamental level, natural capital as a whole make up the resources necessary to sustain all life on the planet. Hence, the need for natural capital is an obligatory requirement for our existence. Above, both fresh water and the oceans' fish stocks were discussed, but there are more features of the natural capital that need attention in the sustainability debate.

First and foremost, the literature talks about natural capital in terms of biodiversity. Hardisty (2010, p.36) claims that "Ecosystems provide a huge range of services to humanity". Among the services Hardisty mentions support services such as soil formation, provision services such as food, regulating services such as erosion control and cultural services such as recreational and educational opportunities. All species have a specific role in the global ecosystem. If one species is exterminated this reasonably means that several other species are also affected. For example, a predatory animal may lose its primary food source, or a population that would normally be controlled by predators (i.e. food source) may grow uncontrolled should the predator disappear (Anderson, 2005). Following the same logic, loss of biodiversity also affects humans. Not least in terms of a reduction of the ecosystem services that Hardisty refers to. However assessment of sustainability risks regarding biodiversity is difficult to conduct since such risks are complex and not very well understood (Anderson, 2005).

According to the World Wide Fund for Nature (WWF) in 2008 the *Living Planet Index* showed a 28 percent decrease in overall biodiversity compared to values for 1970 (Hardisty, 2010). And in 2002 the United Nations Environment Programme issued a report that estimated that a mass extinction crisis will eliminate 24 percent of the world's mammals in 30 years (Anderson, 2005). Habitat destruction and introduction of non-native species (Anderson, 2005) but also overexploitation, pollution and climate change (Hardisty, 2010) are believed to be the major causes for biodiversity loss and mass extinction. The declining biodiversity does not only refer to animals and insects but also to plants and trees. In fact the clearing of forests (in global terms primarily to make room for agriculture) play a significant role in the loss of biodiversity, not least because the forests constitute the habitat for numerous species on earth (Anderson, 2005). In particular the Amazon rainforest is of interest for the sustainability discussion. The Amazon rainforest is estimated to contain up to 30 percent of the world's biodiversity, but with current rates of deforestation in the area Greenpeace warns that virtually the entire forest could be gone in 80 years (Anderson, 2005). An interesting political consideration of the Amazon rainforest is that it stretches over nine different countries which all have their own agenda and claim their own rights to use their land. Even if it would probably be better for the world as a whole to not cut down any more of the rainforest, who owns the right to deny the local population to use the land in a way is best for them? Of course the idea to preserve the rainforest is in consideration of everybody but the same situation applies to many other aspects of the natural capital degradation and climate change issues. This is similar to the carbon dioxide release from traffic around the globe, and even though discussions exist on limiting such release no one can say how any other country should act. Another example of political and commercial pressure to harvest the Amazon rainforest is to allow for expansion of the Brazilian production of soybeans (Anderson, 2005). This shows how human interests such as food production and exports eat away the fundamental ecosystems that sustain the planet. Similar to the decreasing fish stocks and fresh water, the depletion of the forests occurs at an unsustainable rate. That is, eventually the practice will defeat itself as environmental change may decrease the productiveness of the land cleared for agriculture.

Forests do not only provide vital ecosystems, they also provide erosion and climate change prevention (Andersson, 2005). With the following words Hardisty (2010) spots the integration of climate change into other sustainability aspects;

> Climate change overlays and reinforces many of the other sustainability issues, which on their own would provide significant cause for concern. Climate change exacerbates them all. It makes our dependency on fossil fuels more precarious, inhibits our ability to grow food, increases poverty, and is a growing threat to the biodiversity of the planet. (p.41)

Climate change is clearly an issue well incorporated into the sustainability concept. However, the public opinion on the issue seems to not reflect the urgent need for change. The opinion among both the public and among business leaders lags behind the best available scientific knowledge (Hardisty, 2010). This is a quite interesting phenomenon from a risk perception point of view. According to Enander (2005) people in general wants to avoid large consequences. For one thing this means that risks that are perceived as having a potential to cause large consequences evoke strong reactions among people, even if the probability of occurrence for the event is judged as being very small. Climate change, as well as all the other sustainability risks mentioned in this section, must be seen as large consequence risks, which mean that people, both professionals and the public, should consider the risks as unwanted. Maybe Hardisty's understanding that public opinion lags behind the science indicate that people in general have not understood that sustainability risks are of such great magnitude? Maybe could this be the outcome of the fact that governments and media have not taken the threats seriously enough to portray their devastating potential around the world? Another perspective relates to the perceived causes of a negative event. Accidental events that are understood to be caused by the nature are generally accepted simply as natural events that do happen every now and then. If the event on the other hand is caused by human error, or even worse, by malicious intentions, reprehension and criticism is a common reaction among people (Enander, 2005). From this perspective, maybe the lagging public understanding is due to the view that consequences from sustainability risks are seen as inevitable natural happenings instead of inflicted by human activities? The questions are many but this thesis is not aimed at exploring this part of the problem to any further depth. However, judging from the above, mankind has played an important role in creating sustainability risks and the longer we wait the harder it will be to reverse the adverse effects of our collective behaviour (Hardisty, 2010).

3.2 A historical perspective

The term *sustainable development* (SD) originated in the 18th century where it was used in forestry to control the number of trees cut down. The purpose was to ensure a continuous supply of wood for forthcoming generations (Ebner & Baumgartner, 2006). The modern notion of sustainability is considered to be a lot younger. In the 1960's, Rachel Carson's book *Silent Spring* became a symbol of the emergence of the environmental movement (Hardisty, 2010). The popular book brought attention to the disappearance of songbirds in the United States and also determined the cause to be the widespread use of DDT. This resulted in public awareness and discussions that we had reached a point where our way of living could cause long lasting damage to the earth, which previously had been seen as practically limitless. In the following years regulatory powers grew and in 1969 the United States Environmental Protection Agency (USEPA) was formed (Hardisty, 2010). Obviously these new environmental concerns and growing regulatory demands propagated through industry which "…began to see tangible evidence that the days of uncontrolled and unmonitored discharge of waste and effluents were beginning to end." (Hardisty, 2010, p.18). Eventually, the modern understanding of sustainability started to emerge. In 1987 the World Commission on Environment and Development, also known as the Brundtland Comission (since the WCED at the time was led by Norwegian prime minister Gro Harlem Brundtland), in its report *Our Common Future*, adopted one of the most frequently used ethical definitions of sustainable development:

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (WCED, 1987)

In fact this definition of sustainable development can be found in nearly all of the literature on sustainability and sustainable development referenced throughout this report. A similar definition is that of Australia's Intergovernmental Committee for Ecologically Sustainable Development (ICESD), which states that the strategy for ecological development is:

> development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends. (ICESD, 1993)

In the beginning of the 1990's, as the Cold War had ended, there was a globally widespread enthusiasm to let all the money previously dedicated to production of military resources, instead be allocated to making the world a better place (Hardisty, 2010). The concept of sustainability became mainstream. However, the Brundtland Comission's definition of sustainable development was (and still is) inexact (Adams, 2006), and since the discussions on sustainability in recent years have risen significantly the subject has become broad and imprecise, without a common definition (Ebner & Baumgartner, 2006). Or as Hardisty expresses it: "The definition of sustainability, in the modern context, remains elusive." (Hardisty, 2010, p.23). A basic understanding though, is that sustainability entails consideration of both the health of the earth and the opportunity for our children to live a life at least as good as ours (Hardisty, 2010).

3.3 The modern understanding

So what does sustainable development actually mean? Even though the definitions of sustainable development vary somewhat and are generally quite vague, it is possible to extract some key features of this modern quest. The first and most obvious purpose of the notion is to bring more attention to the way we treat our planet. As can be interpreted from the historical perspective above, the concept of sustainable development probably has its roots in the environmental movement, or at least in the growing concern for environmental protection. In standard economic theory development is seen as a quantitative change in terms of growth to gross domestic product (GDP), and a qualitative change in terms of moving from agriculture toward a western mass-consumption society (Munda, 1997). But when the world started seeing numerous devastating environmental accidents people realized that we can no longer act as if financial performance was the only measure of sound development. It didn't escape anybody, the hard facts that were crystalized by accidents like Exxon Valdez, the supertanker that in 1989 ran aground off the coast of Alaska and released 40 million litres of crude oil into the ocean (Hardisty, 2010); or the Bhopal accident in 1984 where a leak of 42 tonnes of poisonous methyl isocyanate gas caused the death of over two thousands (Hardisty, 2010); or the dioxin spill in Seveso in 1976 that lead to an emergency situation involving more than 200 000 people (Pocchiari, Silano & Zapponi, 1986); or the British Petroleum incident in April 2010 when the Deepwater Horizon oil rig exploded and caused a massive oil leak into the Mexican gulf which continued for 87 days (BP, 2010). Aside from environmental concerns, there is also the concern of increasing risks to people. The Seveso and Bhopal accidents especially are both regrettable examples of how technological accidents could lead to onerous consequences to both humans and nature. The growing insight that industrial operations could be harmful in more than one way indicated that maybe there was more to development than just economic aspects.

The Brundlandt commission's definition of sustainable development (refer page 45) flagged that additional to economic development there were other aspects that needed consideration. Thus, over the years the understanding of sustainable development has evolved into comprising three dimensions, namely economic (1), environmental (2) and social (3) sustainability respectively; a concept that is sometimes referred to as the *three pillars* of sustainable development (Adams, 2006). Figure 9 shows one way to illustrate that these three dimensions together make out the bearing foundation for achieving sustainable development. Sustainability means adopting a long term holistic thinking (Carleton, 2009) and these three dimensions can be seen as representing the core values that need to be considered in order to be sustainable.

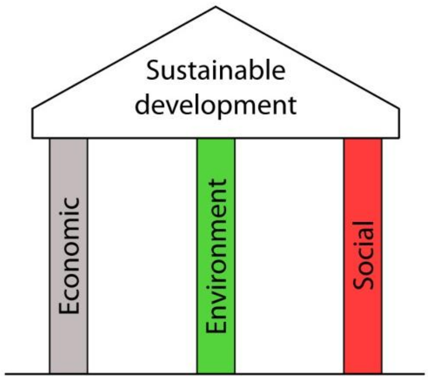


Figure 9: The three pillars of sustainable development.

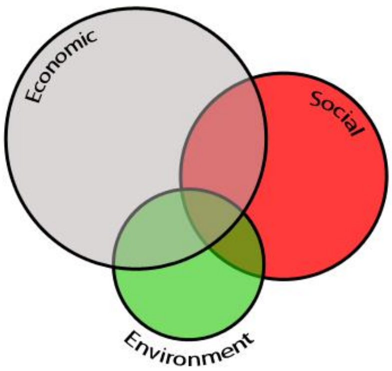


Figure 10: According to Adams (2006) there is a shift in attention among the three sustainability dimensions.

Despite the introduction of the *three pillars*, the concept of sustainability remains difficult to grasp. Harris and Goodwin (2001) briefly present what is included in each of the three sustainability dimensions:

> *Economic* – An economically sustainable system must be able to produce goods and services on a continuing basis, to maintain manageable levels of government and external debt, and to avoid extreme sectoral imbalances that damage agricultural or industrial production.
> *Environmental* – An environmentally sustainable system must maintain a stable resource base, avoiding overexploitation of renewable resource systems or environmental sink functions and depleting nonrenewable resources only to the

> extent that investment is made in adequate substitutes. This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions not ordinarily classed as economic resources
> *Social* – A socially sustainable system must achieve fairness in distribution and opportunity, adequate provision of social services, including health and education, gender equity, and political accountability and participation.
>
> (Harris & Goodwin, 2001, p.xxix)

By this understanding, sustainability introduces a number of complicated contradictions with multidimensional goals. For example, as was described in section 3.1, food production appears to be requiring usage of land that renders a decrease in biodiversity. Not doing this might result in rising food prices, further increasing the burden on the poor. Similarly, changing to more environmentally friendly energy sources might be much more expensive than the sources currently available. In such cases, what should be the decision criteria? What is more important?

The three dimensions of sustainability, illustrated as *three pillars* in Figure 9, indicate that there would be an equivalent weighting among the three dimensions. That is, that the three dimensions respectively constitute, or should constitute, an equivalent portion of the sustainability considerations. This might not be the case. In fact, one could argue that this most certainly is not the case. For instance, Adams (2006) notes that the three dimensions of sustainability can also be illustrated as three overlapping circles with different sizes, as shown in Figure 10. He means by this that there is a need to better balance the attention that each dimension is given. And it goes even further than that. Just by thinking about the discussion so far in this report it is notable that from a historical point of view, financial performance has been a key development driver. Even though there is more to economic sustainability than just financial performance, one can still take this historical progression as a clear indicator that the attention given to economic, environmental and social sustainability is in some way out of balance. At this point though, it is necessary to remember that the illustration in Figure 10 by no means show the actual difference between the dimensions. The illustration only indicates a possible situation. In reality the relation between social and environmental sustainability may very well be reversed. It should also be noted that the relation between the three dimensions may be, and likely is as well, dependent on the situation one is observing. Sustainable development can be pursued at different levels in the world and for each of those levels the meaning and focus of the concept might be slightly different. Some western country's national strategy could perhaps have environmental aspects, for instance in terms of reducing the release of carbon dioxide into the atmosphere, high on the sustainability agenda, whereas one of the developing countries might instead have economic growth or reduction of poverty or diseases high on their agenda. Likewise, different organisations might, dependent on their scope of practise and historical progress, have sustainability agendas that to some degree differ from other organisations.

Another interesting point here is the question whether the three dimensions should be given equal attention at all? As can be expected, around the globe there are more than one opinion on how sustainable development should be addressed. Some people argue that we should not worry too much about issues such as for instance depletion of natural resources. They believe that humankind will eventually discover new ways to substitute natural resources with technological progress, and that overspending on protection against future hard-to-assess risks is inappropriate since it does not allow future generations to come up with better ways to deal with the problems. These kinds of arguments are characteristic for what is commonly called *weak sustainability* (Hardisty, 2010; Munda, 1997). On the opposite side there are people arguing that it is necessary to adopt a precautionary principle to mitigate against what is believed to be overly catastrophic future risks. They mean that we cannot rely on the assumption that future generations will discover ways of handling issues such as natural resource depletion and the like, but we must rather prevent this from happening to be on the safe side. This is commonly referred to as *strong sustainability* (Hardisty, 2010; Munda, 1997). Judging from this, it is not certain that equal weighting of economic, environmental and social sustainability is the most desirable way forward. However, the main conclusion to draw from Figure 10 is that generally speaking it is reasonable to believe that the economic aspect of sustainable development historically has received greater attention than environmental and social aspects. This is also supported by the fact that a similar illustration was used by the International Union for Conservation of Nature (IUCN) in their Programme 2005-8, to represent the need to readdress the balance between sustainability dimensions (Adams, 2006).

3.4 Corporate sustainability

In today's corporate climate the terms of sustainability and sustainable development have become increasingly popular. Epstein claims that "The challenge has moved from "whether" to "how" to integrate corporate social, environmental, and economic impacts – corporate sustainability – into day-to-day management decisions when managers at all levels have significant incentive pressures to increase short-term earnings" (Epstein, 2008, p.19). Possibly one of the greatest challenges with corporate sustainability though, is how to manage the paradox of simultaneous improvement of economic, social, and environmental performances within the company. It requires the organisation's management to actively participate in the process as drivers for the corporate concerns. Just developing sustainability strategies can be a tricky task, but implementation on all levels in the organisation is probably even harder. In order to improve its environmental and social performance, an organisation must identify, measure, and manage its sustainability impacts. Systems, strategies and performance measures must all be reasonably aligned to succeed with the assignment. Despite the difficulties, business leaders have realized the importance of sustainability thinking in order to retain a competitive advantage on the market. Sustainability strategies can help enhance revenues and lowering costs. Moreover, the business risks associated with not being sustainable often entail substantial consequences. Many corporations' reputations have been damaged by negative social and environmental impacts from their activities. This means that careful management of stakeholder impact is of the essence to ensure relationships are not violated. (Epstein, 2008)

In 1994 John Elkington, the co-founder of the sustainability business consultancy SustanAbility, coined the term *triple bottom line* (TBL) (Elkington, 2004) which is another way of seeing the three pillars of sustainable development. TBL, also known by the catchphrase *people, planet, profit* (Carleton, 2009), advances the idea that in a more socially and environmentally aware and regulated world, companies must pay attention to their interaction with society and the environment (Hardisty, 2010). Elkington and his associates felt that there was a need to bring forward an expression that better appealed to the business minded corporate world and focused "…not just on the economic value that they add [the corporate organisations, author's note], but also the environmental and social value that they add – or destroy." (Elkington, 2004, p.3). According to Elkington's terminology corporate managers now have three bottom lines to adhere to, not only profit as before, but also people and planet.

It is not likely that any one company today has been able to completely achieve sustainability, since this is an onerous commitment. Some companies though, have identified their critical impacts on stakeholders and invested time and effort into appreciating and confronting the problems in a systematic way. Epstein (2008) has identified four main reasons why sustainability management is important to corporate organisations:

- **Regulations**. Increasing regulatory powers mean that companies are required to address sustainability in terms of social and environmental aspects. Not conforming to the law has always been a costly failure when companies are exposed to for example penalties and fines, legal costs, potential for closure of operations, and reputational effects related to disobeying regulations.

- **Community relations**. The public is becoming increasingly aware of companies' impact on society and environment. A well-managed sustainability performance may lead to good reputation and improvement of community relations and business performance. Alternatively, mismanaging of stakeholder impacts may cause damage to company reputation and the bottom line.

- **Cost and revenue imperatives**. Sustainability can create financial value for the corporation. Improved company reputation can enhance revenue through increased sales, and costs can be lowered by decreasing regulatory fines.

- **Societal and moral obligations**. Since companies have an impact on society and environment, they also have a responsibility to manage sustainability. Corporate leaders recognize the relationship between business and society and have redefined their economic, social, and environmental responsibilities around the concept of sustainability.

According to Epstein's four reasons, corporate sustainability is effectively a means of sound business management, which for one thing serves to maintain or even develop the organisation's competitive advantage on the market. But corporate sustainability is also a responsibility that the corporations have towards their stakeholders and the society as a whole. As such, corporate sustainability is an organisational commitment requiring attention at management level. In order to successfully implement sustainability, corporations might need a more specific definition of what sustainability entails. For this purpose Epstein (2008) has developed nine principles that integrate well with day-to-day corporate management decision processes:

1. **Ethics**. The company establishes, promotes, monitors, and maintains ethical standards and practices in dealings with all stakeholders.

2. **Governance**. The company manages all of its resources effectively and focuses on the interests of all stakeholders.

3. **Transparency**. The company provides information of its products, services, and activities to allow for stakeholders to make informed decisions.

4. **Business relationships**. The company chooses its suppliers, distributors, and partners not only based on price and quality, but also based on social, ethical,

and environmental performance. The company encourages other parties to do the same.

5. **Financial return**. The company compensates capital investors with a competitive return on investment. Company strategies promote growth and enhance long term shareholder value.

6. **Community involvement/economic development**. The company strives for a mutually beneficial relationship between corporation and community. The company is sensitive to the context, culture, and needs of the community.

7. **Value of products and services**. The company respects their customers' needs, desires, and rights. The company assesses the impact on their stakeholders of products and services.

8. **Employment practices**. The company undertakes human resource management and promote both personal and professional development and diversity among the employees.

9. **Protection of the environment**. The company strives to protect and restore the environment and promote sustainable development through its products, services, and other activities. To achieve this, the company must decide on its commitment to the natural environment. At a minimum the company adheres to local, national, and international regulations and standards on wastes and emissions.

As can be seen, these nine principles of corporate sustainability include economic, social, and environmental aspects and thus reflect the core values of sustainable development.

In summary, why is sustainability important to corporate organisations? Figure 11 shows a schematic illustration that attempts to answers that question.

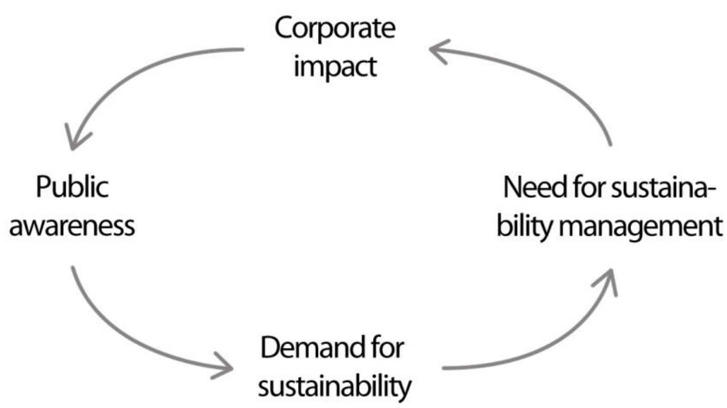


Figure 11: Schematic illustration of the importance of corporate sustainability.

As the historical review of sustainability in section 3.2 revealed, companies do have an impact on society and the people therein (corporate impact). It was also noted that the public is becoming increasingly aware of such impacts (public awareness), and therefore sustainability has also become a demanded feature of stakeholder relations (demand for sustainability). In order for companies to maintain or increase their competitive advantage, they must adhere to the increasing demand for sustainability and include such aspects into management procedures (need for sustainability management). If this process is well handled, their corporate impact will change and the circle is closed. This representation of corporate sustainability has clear connections to Deming's circle of organisational development. In Deming's Circle, also called the PDCA-cycle, the words are plan (P), do (D), check (C), and adjust (A), and the model represents a procedure for continuous improvement of organisational factors (Akselsson, 2008).

Chapter 4 – Investment assessment

Investment decisions are present in many different parts of society. It can be a national infrastructure decision whether to build a railway tunnel or not, a company's decision on which new machine to buy, or it can be a family's decision of whether to buy a new car or not. For the purpose of this thesis though, hereafter a corporate perspective is presumed when discussing investments and investment assessment, unless otherwise noted.

In its widest notion, investment means usage of financial capital that results in long term financial consequences for cash inflows and outflows (Skärvad & Olsson, 2005). Long term, is in this case often refers to several years, sometimes even decades. The time aspect is what constitutes the major distinction between investment and consumption. While the common denominator for investments is that they require capital and are intended to last for a relatively long time (Ljung & Högberg, 1996), consumption is something that is acquired for a more prompt use. From a private economy perspective typical *consumption goods* are groceries and other products that are used near the time of acquisition, while *capital goods* are real estate, dwellings, furniture, and other goods that are intended to be used for a longer time, i.e. investments. The mentioned examples of capital goods are *real assets*. But investment can also be made in shares, bonds, or other *financial assets*. In common for most private investments is that they entail a sacrifice of consumption today, for the purpose of possibly increased consumption in the future. Corporate economy follows the same logic, though in this perspective rather than consumption, one talks of *production* of goods and services. Such production is normally associated with certain costs, and for profit-driven organisations hopefully also some income. Some of these costs refer to acquisition of goods, such as raw material, which is consumed relatively quickly, while other costs refer to acquisition of machines or buildings that will remain for a long time. The latter is what, from a corporate perspective, is regarded as investment. (Persson & Nilsson, 1999)

Except for physical assets such as machines, buildings, and equipment, investment can also be made in intangible assets such as education, research, advertising, and development (Götze, Northcott, & Schuster, 2008). From a historical perspective, production has in recent years become more knowledge-intensive in western industrialised countries. In the 1950s and 1960s production was capital-intensive with a focus on physical investments such as machines and equipment. Lately, the intangible products like services and know-how has become more important, and investment in research and development more prominent (Persson & Nilsson, 1999).

4.1 Classification of investments

Since investments can take many different forms, different ways of classifying them also exist. One is to classify the investments by type, as shown in Figure 12.

1. Foundational investment
2. Current investment
a) Replacement investment
b) Major repair or general overhaul investment
3. Supplementary investment
a) Expansion investment
b) Change investment (e.g. rationalisation, diversification)
c) Certainty investment

Figure 12: Investment classification by type (Kern, 1974 in Götze et al., 2008, p.4)

Foundational, current, and supplementary investments denote investments made in different phases of a company's activities. Foundational investments relate to the start-up of an activity, a new product line, branch, or similar. Current investments refer to continuous investments that are made during normal operations. Current investments include repairs and general overhaul activities, but also replacements. In its simplest form a replacement is a direct substitution of, perhaps, a machine without any substantial changes to its performance characteristics. Often however, replacement investments are made as a means of rationalisation in order to reduce costs or increase productivity. In such cases the investment might instead be classified as supplementary. Supplementary investments are made in existing locations and include expansion, change, and certainty investments. Expansion refers to investments that are made in order to increase the company capacity, while change refers to modification of the company activities. Change investments can be either in the form of rationalisation as was mentioned previously, or in the form of diversification, such as investments needed due to changes of the production areas (e.g. additional or changed products). Certainty investments refer to investments that are made in order to reduce the company risks. Examples in this area might be investment in supplier shares or research and development. As can be noted many of these classifications are similar in some ways, which means that a classification of investments by type might sometimes be ambiguous. (Götze et al., 2008)

Not all investments are aimed at increasing productivity or profitability. Skärvad and Olsson (2005) also mention that investments in internal and/or external environment in a company are common. It can be improvements to the employees' working environment or reduction of environmental impact on ground, water, and air. As such, environmental investments can be either voluntary or mandatory. The latter refers to investments that must be made due to regulatory demands of reduced environmental impact or improved working conditions (Epstein, 2008).

4.2 Investment assessment methods

In many investment assessments a dual-decision situation occurs. First one must decide whether to make an investment or not, then several options might exist so one must decide which option to go ahead with. In order to make informed decisions of this character the decision making process must be facilitated by an investment assessment procedure. Several methods exist for doing such assessments and the following sections outline the basic concept, and some well-known methods for investment assessment.

4.2.1 The general concept of investment assessment

As was noted in the introduction to this chapter, the general meaning of investment is usage of capital resources that result in long term financial consequences in terms of cash in- and outflows. Figure 13 shows a graphical illustration of the basic investment cash flows. Typically an initial investment outlay (denoted I_0) occurs at the beginning of the investment life time (denoted n). The initial outlay includes all one-time costs that occur when the investment is realized. Those costs may be purchases of buildings, machines or equipment, or investment planning work and education. Since this is a cost it is shown as a downward arrow in the figure.

After the initial investment outlay, assuming the invested goods is installed and ready for production relatively close to the time of investment, continuous cash flows associated with the investment will start to appear. In the figure the net cash flow (NCF) is shown as upward arrows as they are assumed to be positive. That is, NCF is the result of the cash inflows minus the cash outflows (CIF – COF = NCF), and is normally positive in the long run or the investment is not profitable. In reality though, the NCF can very well be negative at the beginning of the lifetime if there is a certain time delay until the investment reaches its normal production rate. Examples of CIF are raised income and reduction of costs, whereas COF can be costs of material, service, maintenance, energy etc.

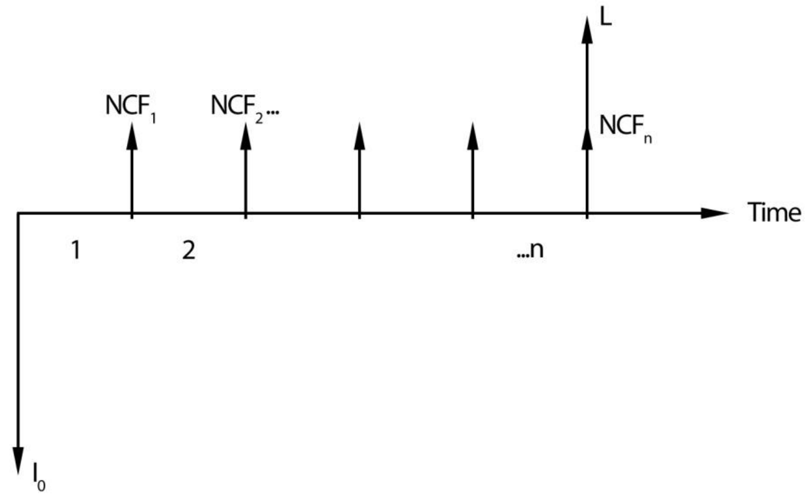


Figure 13: Graphical illustration of investment cash flows.

At the end of the investment's lifetime, there may be a liquidation value (denoted L) left to account for. This is typically applicable for investment objects such as buildings, vehicles and some machines and equipment, where there is a known second hand market. In other cases the liquidation value is often assumed to be zero, since estimation of a reasonable value so far in the future is difficult. Liquidation value is sometimes also referred to as residual value (Persson & Nilsson, 1999).

When determining an investments lifetime, distinction is normally made between economic lifetime and technical lifetime. The latter refers to how long the investment physically will last, whereas the former refer to how long the investment can be considered profitable. Normally, the economic lifetime is the shorter of the two and thus is the most frequently used lifetime for investment assessment. In many investment assessments, experience-based standard numbers of lifetime is used. The time periods for which the net cash flows are summarised to, are often on a yearly basis but other time periods may be utilised.

Whenever a decision to make an investment is made, financial planning must be considered. Financing an investment is rarely done with liquid assets, but rather through some form of long term financing option. Financing in terms of, for instance, a bank loan can be illustrated by the opposite to Figure 13. That is, a large payment is made at the start (to cover the initial outlay I_0) and then continuous refunding applies. (Ljung & Högberg, 1996)

Some well-known methods for investment assessment are described in the next sections.

4.2.2 Discounted cash flow methods

For a company to be able to analyse whether an investment is profitable or not they must determine that the net cash flows over the investments lifetime exceeds the initial outlay. This is what in referred to as a profitable investment. (Götze et al., 2008) The straight forward procedure would be to simply sum up all the net cash flows and the liquidation value and then subtract the initial outlay. However, an important feature that was not mentioned in the general concept above is the need to consider discounting of the cash flows. This arises from the fact that money in the future is worth less than money in the present. For example, if a company buys something today but postpone their payment to the next year, they will be forced to pay interest, which means that their investment will cost more the next year than it does today, at least if the cost is expressed in today's value of money. For example if a payment of 100SEK today is postponed one year and the rate of interest is 12 percent, then the delayed payment will be of 112SEK. The mathematical operation is:

$$100 \times (1 + 0{,}12) = 112$$

The expression in brackets is really the interest factor (which from hereon is called compounding/discounting factor), which can be written as $(1+r)$ where r is the rate of interest, or discount rate. If the payment is postponed two years instead of one, the mathematics would be:

$$112 \times (1 + 0{,}12) = 125{,}44$$

This means that the value after one year is simply multiplied one more time with the discounting factor. Obviously this can be continued for a choice of years and the general expression of the compounding factor becomes $(1+r)^n$, where n denotes the number of years into the future for which the cost is to be calculated. Analogous, one can also use the compounding factor to calculate how much 100SEK next year is worth today, i.e. move a payment backwards in time. Instead of multiplying one simply divides the payment with the compounding factor instead, though now the name changes to discounting factor. This means that 100SEK next year is worth about 89SEK today, according to the following mathematics:

$$\frac{100}{(1 + 0{,}12)} = 89{,}29$$

Now turning back to the investment assessment procedure it is easily realised that in order to compare all cash flows for an investment, including initial outlay and liquidation value, some of the cash flows must be repositioned in time. For this operation, the cash flows must be compounded or discounted to a certain point in time. A few common methods which include discounting are presented below.

Net present value method (NPV)

Net present value (NPV) is the method that is closest to the general concept described above. In the NPV method all cash flows are moved to the present so that they all can be compared in the present value of money. NPV can be calculated with the following formula:

$$NPV = -I_0 + \left(\sum_{i=1}^{n} \frac{NCF_i}{(1+r)^i} \right) + \frac{L}{(1+r)^n}$$

where: I_0 is the initial outlay;
NCF_i is the net cash flow for time period i; and
L is the liquidation value at the end of the lifetime (year n)
r is the discount rate in decimal form.

An investment is profitable if the NPV is equal to or above zero. If NPV is zero, the rate of return equals to the adapted discount rate. Hence, the discount rate can be said to reflect the investor's preferred rate of return (Persson & Nilsson, 1999). When comparing different investments, the one giving the largest NPV is the most profitable one (Ljung & Högberg, 1996).

Annuity method (AM)

In the annuity method, instead of calculating the total present value of an investment one calculates a yearly equally large cash flow for the entire lifetime of the investment. In this so called *annuity* the initial outlay and the liquidation value is included.

Similar to the NPV method, an investment is profitable if the annuity is equal to or above zero, and the alternative with the highest annuity is the most profitable one. (Ljung & Högberg, 1996)

Internal rate of return method (IRR)

The internal rate of return method (IRR) basically calculates which discount rate makes the NPV turn out to zero. Essentially, this means calculating the discount rate *r* when the NPV formula above is set to zero. The resulting discount rate is called the investment's *internal rate of return*, and denotes the yearly rate of return that the particular investment will give. (Ljung & Högberg, 1996)

An investment is profitable if the internal rate of return is higher than the normally used discount rate. Among several investment options the one giving the highest internal rate of return is the most profitable one (Ljung & Högberg, 1996).

Pay-back method (PB)

As the name suggest, the pay-back method determines how long it will take for an investment to earn back the invested capital. In its simplest form, PB does not account for any discount rate. In this case the PB-time is calculated simply by adding all the expected yearly (or other time period) NCF until a sum equivalent to the initial outlay is reached. The corresponding number of years is the PB-time. To determine if the investment is acceptable or not the calculated PB-time is compared to a predefined time period on the investor's preference.

When discounting is considered, the PB-time is calculated as the time until the discounted net cash flows are large enough to render a NPV that is zero. That is, the time until the NPV is zero. Using the NPV formula above, the year i can be calculated for an NPV of zero. The PB-time then equals to i years, and is compared to the investments total lifetime to determine if the investment should be made. (Persson & Nilsson, 1999)

4.2.3 Qualitative and multi-criteria methods

In many investment assessment situations the important parameters may not be easy to determine. The discount rate is one such parameter, that every company decides on its own and that lays the foundation for many of the most common investment assessment methods. The discount rate thus entails a level of uncertainty within the assessment. Likewise, it is inherently uncertain to try to determine cash flows that will occur in the future. The further into the future an event occurs, the harder it is to assess. Therefore many of the basic investment assessment methods are filled with uncertainties. Sometimes it might also be virtually impossible to value the benefits in accurate monetary terms, or perhaps there are many different criteria that need to be evaluated to make an informed assessment of expected cash flows. Cash flows from non-physical investments such as for example research and development may also be very difficult, if not impossible to determine. In such cases qualitative and/or multi-criteria investment assessment methods can be useful.

Profile chart

A profile chart is in essence a checklist with a multiple grade scale to assess and value certain factors considered relevant for the particular investment. The assessment scale often has five grades and is of a qualitative ordinal character, such as:

1. Low/very negative
2. Medium-low/negative
3. Medium/indifferent
4. Medium high/positive
5. High/very positive

Table 3 presents a brief example of a profile chart for investment in a development project.

Table 3: Example of a profile chart (Persson & Nilson, 1999)

Factor	Grade				
Market					
Competition	1	2	3	4	5
Client structure	1	2	3	4	5
Distribution	1	2	3	4	5
Need for information	1	2	3	4	5
…	1	2	3	4	5
Production					
Available competence	1	2	3	4	5
Environmental issues	1	2	3	4	5
Capacity	1	2	3	4	5
Personnel resources	1	2	3	4	5
…	1	2	3	4	5

When all factors have been valued and graded, lines can be drawn between the selected grades so that the *profile* becomes visible. The profile chart provides a simple and intuitive way of illustrating the strengths and weaknesses with a certain investment. (Persson & Nilsson, 1999)

Multi-attribute utility theory

Multi-attribute utility theory (MAUT) is just one of many multi-criteria decision making aiding tools. It is sometimes also referred to as additive utility theory (Clemen, 1996). In MAUT the decision is broken down into a set of objectives, which are ordered in a specific hierarchy.

Figure 14 shows an abbreviated example of the objectives hierarchy for evaluating alternative-energy technologies.

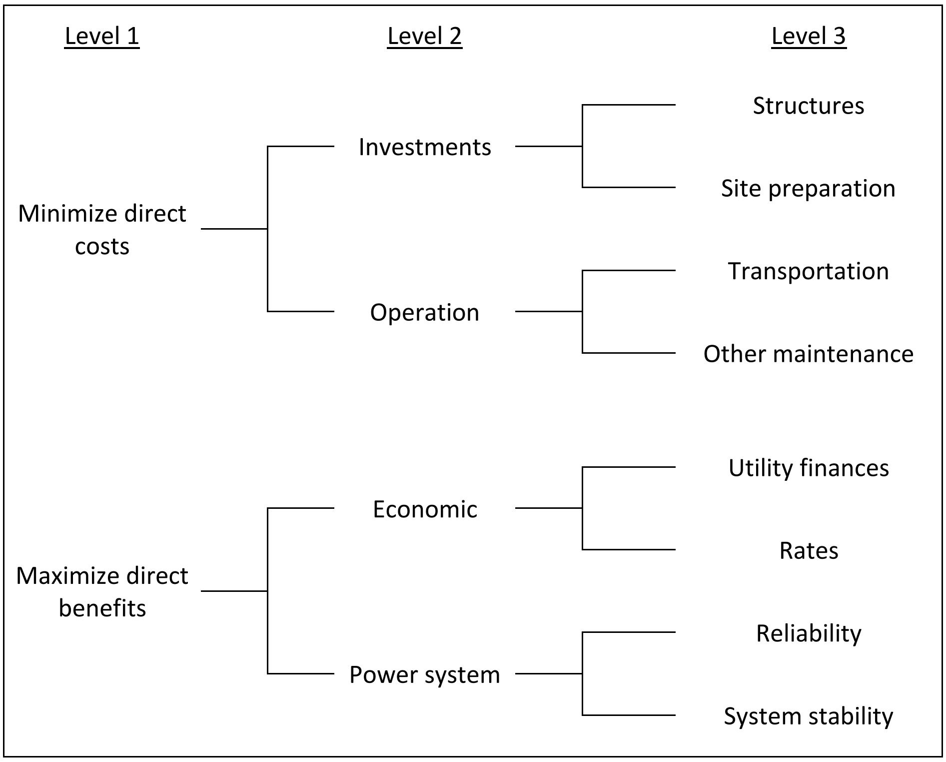


Figure 14: Objectives hierarchy for evaluating alternative-energy technologies (Clemen, 1996).

Cardinal utility functions are then used to evaluate the different alternatives on the basis of the identified objectives. Essentially it is the third level objectives that are evaluated. The cardinal scale works in the way that the alternative that is the most preferred for a certain objective, is given a utility score of 1. The alternative that is the least preferred is given the score 0. All other alternatives are given numbers in between 0 and 1, calculated in a cardinal manner such as for example using linear interpolation.

Clemen (1996) exemplifies the utility function with an automobile example; say that one is interested in buying a car and that the evaluation of cars is based on two main objectives, namely price and life span. There are three cars to choose from; Portalo, Norushi, and Standard Motors. Price and life span for each car is according to Table 4 below.

Table 4: Price and lifespan for the three cars.

	Portalo	Norushi	Standard Motors
Price ($1000s)	17	10	8
Life span (years)	12	9	6

Starting with the price, assuming that the lowest price is the most preferred, the Standard Motors car is the best alternative, and the Portalo is the worst. Thus they are scored 1 and 0 respectively. Using linear interpolation the Norushi's price is found to lay approximately 78% of the way between $17000 and $8000, thus the score for the Norushi is set to 0,78. The same logic applies to the life span, where 12 years is considered the best alternative, and 6 years is considered the worst. The Portalo gets scored 1 and the Standard Motors gets scored 0. 9 years is exactly halfway between 12 and 6 years so therefore the Norushi gets scored 0,5. The total scoring for each car is according to Table 5 below.

Table 5: Utility scores for the three cars.

	Portalo	Norushi	Standard Motors
Price ($1000s)	0,00	0,78	1,00
Life span (years)	1,00	0,50	0,00

At this stage one can determine which car is the best regarding each decision objective separately. But which car is the best overall? In order to make this judgement one needs to decide the relative importance of the decision objectives, or in other terms assign weights (denoted k from hereon). Say that the decision maker prefers both objectives to be weighted equally, i.e. $k_{price}= k_{lifes\ pan}= 0,5$. Then the total utility (denoted U) for each car can be calculated as follows:

$U_{Portalo} = 0,5(0,00) + 0,5(1,00) = 0,5$
$U_{Norushi} = 0,5(0,78) + 0,5(0,50) = 0,64$
$U_{Standard\ Motors} = 0,5(1,00) + 0,5(0,00) = 0,5$

Another decision maker might consider price to be twice important as life span and thus assign the weights $k_{price}= 0,67$ and $k_{lifes\ pan}= 0,33$. In such case the total utility for each car would be:

$U_{Portalo} = 0,67(0,00) + 0,33(1,00) = 0,33$
$U_{Norushi} = 0,67(0,78) + 0,33(0,50) = 0,69$
$U_{Standard\ Motors} = 0,67(1,00) + 0,33(0,00) = 0,67$

Returning to the alternative-energy technologies in Figure 14, it is noted that the decision objectives have been expanded to comprise three levels. Utility scoring is made at level 3, and to calculate the total utility weighting is necessary to be made at all levels. First, one need to determine the relative importance among level 3 objectives, then the relative importance at level 2, and finally at level 1. For clarity, let the weights at the three levels be denoted k for level 1, m for level 2, and p for level 3. Then the hierarchy can be clarified according to Figure 15.

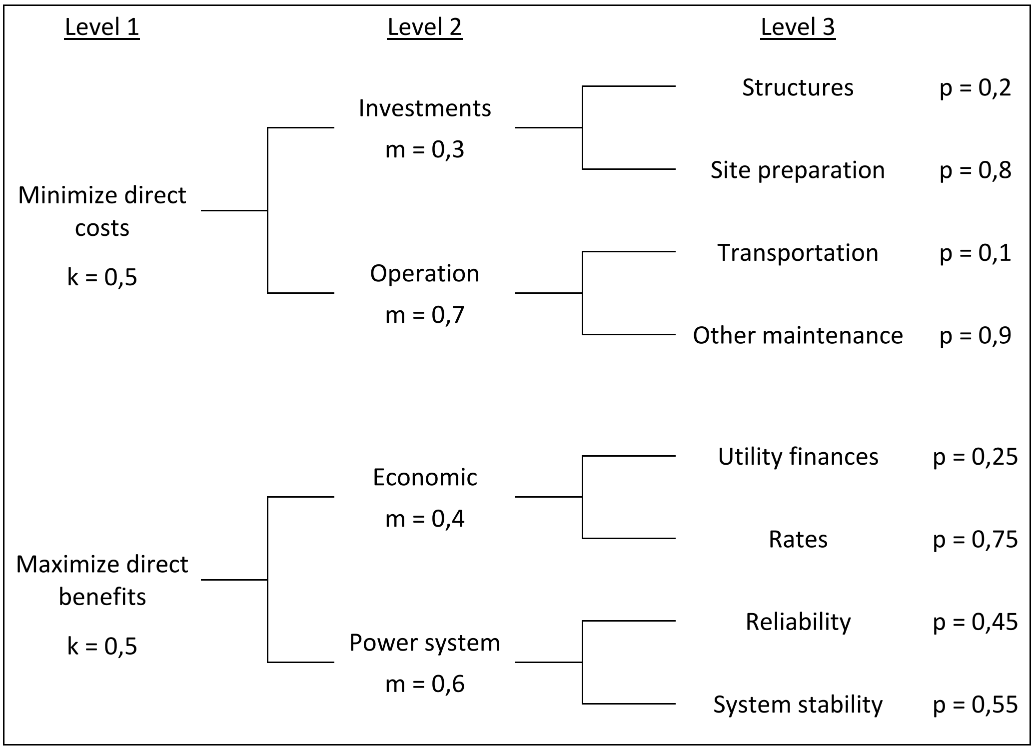


Figure 15: Objectives hierarchy for evaluating alternative-energy technologies, including weights, after Clemen (1996).

Note in the figure that the weights for all level 1 objectives (*k*) summarise to 1. Similarly, in each group of level 2 objectives, the weights (*m*) also summarise to 1. Following the same logic, for each group of level 3 objectives the weights (*p*) summarise to 1 as well. Put in the words of the example in Figure 15, the weights can be interpreted in the following manner: In the overall assessment *k* denotes the relative importance of *Minimize direct costs* and *Maximize direct benefits* respectively. Within the *Minimize direct costs* objective, *m* denotes the relative importance of *Investments* and *Operation* respectively. Analogous, within the *Investments* objective, *p* denotes the relative importance of *Structures* and S*ite preparation* respectively.

Many different methods exist for assessing the preferred weights. In the example with the three cars, one can for example have a preference of how much one year extra life span is worth in monetary terms and then assess the weights from this standpoint. When less quantifiable decision objectives are used other methods are required both for assigning the cardinal scores and for assessing the weights. Clemen (1996) further discusses some common issues associated with using additive utility functions, or multi-attribute utility theory.

4.3 Investments in fire protection measures

Investment in fire protection measures is an area that deserves some special attention. Not only because it is a core part of the present thesis, but also because application of traditional investment assessment methods is somewhat more difficult when it comes to investments in fire protection measures. Especially if the fire protection measure in question is not required by the relevant building code, the investment assessment might be extra difficult (Johansson, 2002b).

The traditional investment assessment methodologies described in the previous sections all make use of some form of incoming and outgoing cash flows. For an investment in fire protection measures however, such cash flows are sometimes difficult to define. In most situations investments are made to improve profitability in one way or another. In such assessments the costs of the investment are exceeded by its benefits. For example, if a new machine is installed in a production facility, the aim is to increase production and gain further revenue from increased sales. That is not the direct reason behind investments in fire protection. Rather, one strives to reduce the risks within the organisation, both in terms of physical threats and intangible threats. Therefore, investments in fire protection do not necessarily provide any increases in revenue and the costs are therefore difficult to balance out. Say that a company normally uses the pay-back method with a maximum of three years as the bench mark pay-back period and that they try to employ the same method for assessing an investment in fire protection. The costs are quite easy to assess but what should be taken as income? Fire protection measures provide some degree of risk reduction and Johansson (2002b) suggests that one might try to estimate the risk reduction's intrinsic monetary value and treat this as an income from the investment. However, a primary difficulty is how to assess the risk reduction. How large is it and how can it be valued? Accomplishing such estimation would, however, allow for easy comparison and judging of different investment options, since the monetary scale is familiar to most people. Johansson's methodology further suggests the use of quantitative risk analysis to calculate the probabilities and consequences for a set of fire scenarios, hence providing the level of risk reduction to apply the monetary estimation on top of. Intuitively one note that this type of assessment procedure might become quite time consuming and requires a great deal of knowledge about risk analysis methods.

Assessment of fire protection investments are also dependent on the building in which it is intended to serve. If the fire protection is part of a completely new building (e.g. a new factory) it can be included as just another cost within the entire building. The building itself is probably planned as a means of increasing revenues and therefore the additional costs from fire protection are included in the investment assessment for the building as a whole. In such situations the only difference between investing in fire protection or not might be that the pay-back period becomes slightly longer. Investments in fire protection intended to serve in an existing building are more uncertain. Then the problem of how to find an income to balance the costs appears again. An important factor that adds to the uncertainty is the life time. It can be hard to assess how long an existing building will remain in use, or the fire protection measure's expected life time might have to be reduced according to that of the building. The standard (e.g. regulatory demands) to which the building was constructed may create another source for uncertainties.

In some companies the benefits from investment in fire protection might be quite obvious even though they are not strictly quantified and monetised. It can, for example, be that some production units imply bottle necks in the company's production chain and therefore the organisation as a whole is very much dependent on reliable operations in that specific unit. Then the investment might not require any further assessment just because the risks of not protecting it are simply too large.

Chapter 5 – Risk management, sustainability, and investments

This report has so far separately discussed risk and risk management, sustainability, and investment assessment. In this chapter a discussion is made on how these segments relate to each other, both for the good and for the bad.

5.1 Risk management as a tool for sustainability

Risk management and sustainability are in fact closely related to each other. On a general level the notion of sustainable development can be seen as an attempt to manage the risks that human activities pose towards our opportunities to continue to progress and develop. Not least this is reflected in the dominating definition of sustainable development presented in Chapter 3 (refer page 45), which effectively states that we must consider how development in the present may impact future generations. Comparing these impacts on future generations to unwanted and potentially harmful events, this can be said to be exactly what risk management is about; identifying potentially harmful events and taking the relevant action to mitigate the risks they pose. Management of sustainability risks is as important as any other type of risk management. However, sustainability risk management is more complex than traditional risk management since the risk situation is generally less defined in the former (Anderson, 2005). From a corporate perspective sustainability also includes sustaining the business itself, and any damages and losses that occur may threaten the company objectives. Fire can be a very destructive threat to a business and, as was noted in section 2.4, is an important consideration in risk management. Clearly then, managing risks and managing sustainability are closely related. So, managing for sustainability can be said to be part of risk management, just as managing risks can be said to be part of sustainability management.

Krysiak (2009) also notes that since sustainability includes consideration of both the present and the future it can be interpreted as a framework for assessing how decisions in the present may impact individuals in the future. He claims therefore that "at the core of sustainability lies futurity." (Krysiak, 2009, p.483). However, playing on Krysiak's words, one might also say that at the core of futurity lies uncertainty. That is, attempting to predict how present decisions will impact the future cannot be done with certainty. Krysiak wants to communicate that in order to make truly sustainable decisions, uncertainty must be included into the decision making process. Thus, he means that sustainability must be stated in terms of risk and he therefore redefines sustainability based on "…limiting the probability that a future generation is harmed." (Krysiak, 2009, p.484). By this concept Krysiak shows how the ethical concept of sustainability provides a link to well-recognized tools for risk management, and thus that these tools are useful in the process of applying sustainability as a framework for assessing decisions with long lasting consequences.

5.1.1 Fire protection and sustainability

Fires may lead to several negative sustainability impacts, regardless if it is in industrial, commercial, or residential circumstances. Examples of sustainability impacts from fire include release of toxic materials and greenhouse gases into the air, significant consumption of water for fire fighting purposes, leakage of contaminated fire fighting water run-off into the soil or nearby aquifers, loss of income due to stoppages of production, increased costs and environmental impacts due to reparation or rebuilding (including production and transports of new building materials), health impacts to both workers and the general public, loss of jobs, risk for permanent shut-down of heavily damaged production units, local community impact due to lost jobs etc. Addressing potential fire risks can thus obviously be of significant value for increasing sustainability. (Kasmauskas, 2010)

Figure 16 shows an indicative graph of how fires result in an environmental impact in terms of increased carbon emissions during a building's life time.

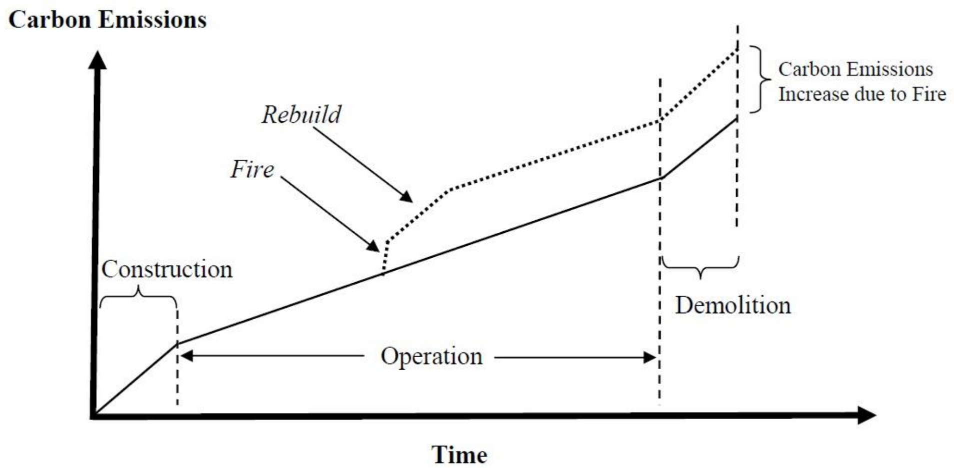


Figure 16: Building life cycle carbon emissions, including impact by fire (Wieczorek, Ditch & Bill, 2010, p.3).

Fire protection and sustainability share the common goal of making the world a better place and Grant (2010, p.6) argues that fire protection is inherently contributing to sustainability, since "fire protection strives to preserve and maintain.", which is much the same as sustainability can be said to do. Around the world there are many different certification programmes for sustainable building design. Examples include the United States Green Building Council's (USBGC) Leadership in Energy and Environmental Design (LEED) rating system, the Building Research Establishment Environmental Assessment Method (BREEAM, mostly used in the UK), and the Green Star rating system used in Australia (Dent, 2010). However, as Hofmeister (2010) and Kasmauskas (2010) note, most of these rating systems do not credit any fire protection measures. This is an unfortunate fact that reduces the incentives to install fire protection measures as a means of not only increasing sustainability but also reducing the fire risks in general. The sustainability benefits from fire protection do exist however and Wieczorek, Ditch and Bill (2010) present experimental results to support such statements. In a large scale fire test they burnt two identically built and furnished living rooms, where one fire was extinguished solely by fire brigade intervention. In the other, residential sprinklers controlled the fire until it was completely extinguished by fire brigade intervention. The fire test results showed that aside from the obvious loss prevention, automatic sprinklers could provide several benefits including the following:

- Emissions of greenhouse gases were reduced by 98 percent.

- The amount of extinguishing water was reduced by 50 to 91 percent.

- The extinguishing water run-off contained significantly less pollutants thus limiting the risk for environmental impacts from waste water.

- Flashover was prevented thus limiting the risk of fire spread to adjacent rooms (in the non-sprinklered test flashover occurred prior to fire brigade arrival).

Dent (2010) explains another interesting aspect of sprinkler protection. Today, the use of advanced fire engineering can provide very user specific building designs. Making such specific designs may not be a particularly sustainable approach since it may reduce the flexibility of the building and introduce problems in the case of future refurbishments for new tenants. However, by the installation of sprinkler protection the building's flexibility for future usages is increased. Increasing the flexibility of a building can very well be seen as increasing the sustainability of the building.

Altogether the above examples show that sprinkler protection inherently contributes to sustainability. Logically this also means that fire protection in general can provide similar benefits, even though the specific extent of the benefits may vary between different fire protection measures.

5.2 Economic barriers to sustainable development

Sustainability and sustainable development might not have worked as well as desired. Realistically, if everyone could just see the true values of our surrounding and make a decent effort to preserve it, the progression into sustainable development would be well under way. But it is not that simple. In fact sustainability is to some degree inhibited by the very core principles our western industrialized societies are based on, namely economics. To understand the economic barriers to sustainable development, a brief look at some historical facts regarding the economy is necessary.

Traditional economics actually include five main schools, although they are sometimes simplified into three categories, being Marxistic, institutional, and neoclassical theory respectively. Even though some tensions exist in the mainstream economic approach, neoclassical theory is the most prominent theory by the means of dominating the fields of education and research in the western industrialised countries. Neoclassical theory has its roots back in the 1870s when classical economic theory started to get influenced by natural science, for example the mechanics by Isaac Newton. This meant that supply and demand was seen as forces on the market, which as a whole was assumed to work in a mechanical manner. Economics became ever more mathematical and the understanding of marginal economics had a breakthrough. (Söderbaum, 1993)

Surely much has happened in the world of economics since the introduction of the neoclassical theory but many of its basic features remain in the economies of today. For one thing, it is quite noticeable when it comes to sustainability and environmental issues. Söderbaum (1993) identifies a number of shortfalls with the neoclassical theory in relation to environmental problems. Firstly, environmental issues are of multidimensional character. How can political interests manipulate the markets? How is the environment affected by a certain feature of the market? How does this in turn impact plants, humans, animals, or other living organisms on our planet? According to Söderbaum however, the neoclassical theory mainly promotes a one-dimensional analysis of the market where money is seen as a suitable measure for everything. Clearly though, monetary valuing is one of the hardest parts when it comes to sustainable development. Secondly, and related to the previous point, neoclassical theory is based on a series of approximations where, for example, corporations on the market are assumed to always maximise monetary profit, and people are assumed to always maximise the benefit. As such, on the market the individual behaves as a rational decision maker with complete information of alternative options, which is quite unlikely to be true. Neoclassical theory has received some criticism regarding this view of the human being. Social research implies that the human is not only an individual being, but is also part of a number of collective constellations. Consideration for family, friends, the country, or even the world as a whole may influence the decisions of the individual person. Söderbaum reasons that by neglecting complex relations like this the neoclassical theory misses much of what most people think is an important part of the problem with environmental issues. Furthermore, taking another step back in history, we meet one of the most important ancestors to the neoclassical theory, namely the classical economist Adam Smith. He and his contemporaries realized that morality and politics were important elements of all national economics. Adam Smith claimed that the exchange that takes place on the market is beneficial for both the seller and the buyer. He would have stated at some time that it is not the brewer's, baker's, and butcher's kindness that gives us our lunch, but rather their assertion of their own interests (Söderbaum, 1993). In this context, Adam Smith also talked about something he referred to as the *invisible hand*, which would make things right even though the individual players would emphasize a self-interest case. The thesis of the invisible hand states that "if you only think about yourself it will turn out good for the entire society by the help of the invisible hand. Every attempt to adhere to other people's interests will only lead to a worse result for the whole, that is, the society." (Söderbaum, 1993, p.26, author's translation). Today though, and especially with consideration of sustainability, the thesis of the invisible hand is quite old-fashioned. Companies that focus only on their own interests without consideration of the society and the environment could be accused of egoism and become discredited among the general public and targeted with product boycotts. Only focusing on your own interests is simply not a viable option for companies. That we saw in Chapter 3. But as described below current investment assessment tools are also an integral part of the economic barriers to sustainable development.

5.2.1 Insufficiencies with present investment assessment tools

The traditionally utilised methods for investment assessment (such as NPV, IRR, PB etc.) do entail some insufficiencies when it comes to sustainability. Problems that exist on a micro-economic level seem to be the result from a lagging macro-economic view of the modern society. According to Hardisty (2010) the way we measure national and global economic success, namely the gross domestic product (GDP) and global product (GP) respectively, has not kept pace with the changing world. In a harsh attack on GDP, Hardisty claims it to actually be a very poor measure of wealth, wellbeing, and happiness that promotes unsustainable development.

GDP is the topmost official measure of development in the society. National governments monitor the GDP to be certain that it keeps increasing and ensures that the development does not falter. If it slows down, as in the global financial crisis of 2008-2009, massive efforts are made to get the continuous growth back on track. Haridsty (2010) mentions that during the financial crisis as much money was spent on stimulating the economy as the OECD (Organisation for Economic Cooperation and Develpoment) estimates will be needed to decarbonize the entire world's economy and mitigate worst climate change effects. GDP however, neglects much of what is important in achieving sustainable development. GDP measures the total value of all market traded goods and services. But that is as far as it goes. Unfortunately no externalities are included. As a direct implication of this, the Exxon Valdez million litre oil spill in Alaska turned out to boost the GDP because of the costs of all the clean-up work (Hardisty, 2010). It is not unlikely that the recent Deepwater Horizon incident in the Mexican gulf may produce a similar result (refer section 3.3). And this is only one fundamental flaw within GDP, Hardisty lists several more:

- GDP does not include unpaid work so all time that is spent caring for children, the elderly or sick family members, doing housework, doing volunteer societal work, etc. is excluded from GDP even though this work is utterly important for the development of the society.

- GDP does not account for externalities so none of the damage done to the environment or society by the economy is included. GDP can thus be very strong, meanwhile the environment and society is degrading from polluted soil, air, and water as well as negative health impacts due to the activities undertaken to produce goods and services.

- GDP counts expenditures on protection from environmental damage as a positive. Examples include the provision of bottled water as a result of pollution, medical costs associated with illnesses triggered by environmental damage (e.g. lung diseases due to air pollution), and remediation of environmental damages. Treating costs that arise due to our depreciation of the planet as a positive contribution to GDP does not promote a sustainable development.

- GDP does not account for natural capital depreciation. The depletion of natural resources and biodiversity is a serious threat to our planetary sustainability but GDP only reflects the value of the goods and services produced from those resources and not the value of the used-up resources themselves.

Hardisty is not alone in claiming GDP to be an incomplete economic measure, the Atkinson Foundation (no date, in Carleton, 2009) states that GDP is a narrow indicator that sends confusing or possibly even dangerous signals to policy makers', and Venetoulis (2010) mentions that GDP, only measuring the dollar value of economic activity, was never designed as a measure of progress, even though policy makers use it that way.

The problems with GDP are also reflected in organisational decision making. Most organisations use the NPV or PB method as a basis for project and business decision making (Hardisty, 2010; Epstein, 2008). However, the problem is that these methods inherently focus on short term financial results (Carleton, 2009), and are narrow in scope and do not necessarily account for issues external to the project in question. The only externalities that might be included are those that are regulated and mandatory such as taxes, fees, royalties or penalties (Hardisty, 2010). This means that most of the social or environmental damages done by a certain project are excluded from the analysis. Another significant impediment to implementing sustainability into decision making is that there is a substantial difficulty in placing monetary value on social and environmental issues and damages. In environmental discussions for example, one might talk about the number of birds that have vanished, or the tonnes of carbon dioxide that are released into the atmosphere every year. The problem though, is to find a suitable way to make decent trade-offs between monetary valued items and non-monetary items. As a result, the current financial and economic attitude remains virtually unaffected by the idea of sustainable development. Hardisty (2010) also talks about a "NPV-IRR trap" that can be especially visible when evaluating energy efficiency projects. When an organisation is about to analyse a project of this type, the internal rate of return is assigned to match that for normal capital investments. However, since the costs of carbon emissions are often not included in the assessment it is effectively impossible for the energy efficiency project to satisfy the targeted IRR. The project might provide a negative NPV because even if they are profitable, they are not profitable enough to meet the IRR demands. By including social and environmental costs however, the assessment might turn out different and the project might be profitable. This "NPV-IRR trap" is according to Hardisty one of the most significant barriers to sustainable development within the industry.

5.3 A new way

Except for some insufficiencies with the present investment assessment tools, impediments to sustainability also exist on an organisational level. Epstein and Wisner (2001) declare two significant such impediments. Firstly, costs for sustainability improvements are often seen as discretionary and environmental, with health and safety (EH&S) managers having a hard time presenting a viable business case in order to get the required funding for social and environmental programs. Secondly, managers often do not know how to translate sustainability strategies into action. Epstein and Wisner further states that for EH&S managers to get the relevant funding approved they must be able to clearly explain the business value with the social and environmental programs. For this purpose Epstein and Wisner present the use of balanced scorecards as a means of measuring, and subsequently implementing, sustainability strategies. The interesting part about this is that Epstein and Wisner take a well know management tool, the balanced scorecard, and complement it with sustainability factors as an additional group of performance indicators. Expanding on this, Jiangtao and Pin (2010) have investigated how a sustainability balanced scorecard influences the decision process for evaluative and investment decisions. The balanced scorecard normally includes four sectors according to which business performance can be measured. These four sectors are financial, customer, internal business process, and innovation and learning (learning and growth) (Kaplan & Norton, 1992). In their research Jiangtao and Pin let 156 participants (selected among students at a university offering account courses) review a number of predefined investment options based on a fictional company's strategic objectives and the information within the balanced scorecard. The different options were linked to different balanced scorecards, where some included environmental data either embedded in the other four sectors, or in an additional fifth sector focused on environmental performance indicators. The research data indicated that the participants in fact chose the more environmentally friendly alternative, but only if the environmental data was included as a fifth, separate sector in the balanced scorecard. Thus, the research shows that inclusion of environmental data into the decision process may indeed affect the investment decision. This new way of extending the present tools for business management, particularly in terms of investment decision procedures, provides a valuable input to the proceeding work with this thesis.

Chapter 6 – Development of an extended model for assessment of investments

This chapter presents the development of an extended model for the assessment of investment in fire protection measures. As shown in Figure 17, the proposed model provides a link between sustainability, risk management, and investment in fire protection. The details of the extended assessment model are set out in the following subsections.

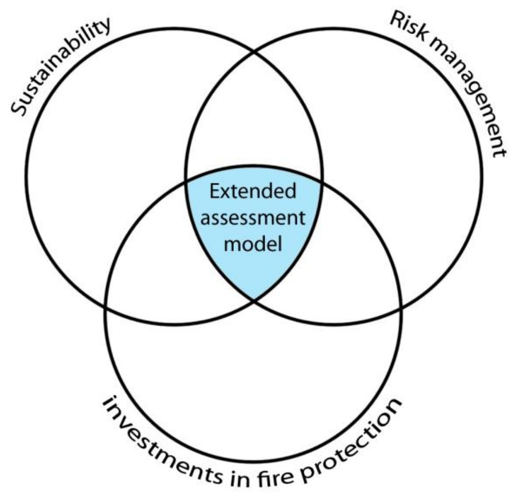


Figure 17: The proposed assessment model provides a link between, sustainability, risk management, and investments in fire protection.

6.1 Design process

When designing methods or models it is extremely important to consider the design process, as this is different from other sciences. Traditional descriptive science strives to acquire understanding and knowledge of how something in the world works. Designing a model on the other hand is concerned with developing an artefact that fulfils a predefined purpose. (Hassel, 2010)

As Hassel (2010) notes, most design research is aimed at developing physical artefacts. The model to be designed in this thesis is, however, of a more intangible nature where a set of thoughts and ideas are bound together to form an extended model for assessment of investment in fire protection measures. As such the model is not necessarily to be considered a physical artefact, but the same design process considerations are still applicable since an assessment model can be seen as an abstract artefact (Hassel, 2010; Abrahamsson, 2009). The design of a model can be characterised on three levels where purpose (1) answers the question *why* the model is needed; function (2) answers the question *what* functions the model must perform; and form (3) answers the question *how* the final model performs the desired functions (Abrahamsson, 2009). At some stage it will also be necessary to investigate how well the developed model performs in relation to its purpose, function, and form. Therefore an evaluation is another important step in the design process.

For the purpose of designing an extended model for the assessment of investment in fire protection measures, the design process shown in Figure 18 is followed, except that *construct method* is rather called *model construction*. Some deviations may occur, which is described within the relevant subsection (refer sections 6.2 through 6.5).

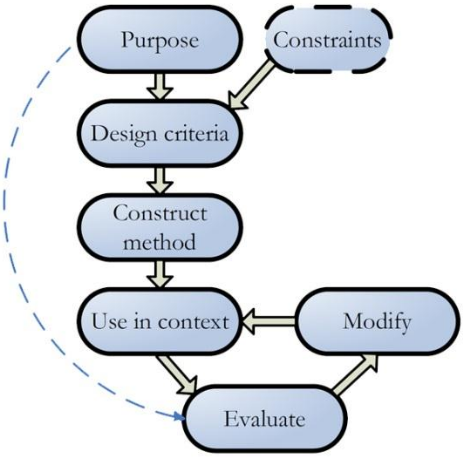


Figure 18: Process for designing methods (Abrahamsson, 2009, p.23)

6.2 Model purpose

The extended model for investment assessment is intended to bring attention to aspects of investment assessment that are traditionally not always considered in a structured manner. The model should make visible how fire protection inherently does add to the overall sustainability performance for the corporation. More specifically the model should strive to achieve the following purposes:

- Raise awareness at business management level that investment in fire protection measures entail benefits that range beyond financial performance, and that fire protection measures inherently provide a degree of sustainability.
- Provide a tool for business management or equivalent to assess what impact a particular fire protection measure, or combination of fire protection measures, might have on sustainability performance factors.
- Provide a tool for business management or equivalent to assess which site or which building on a particular site where a fire protection measure would generate the highest benefit (prioritisation).
- Provide a tool for the sustainability-minded organisation to assess fire protection investments in a structured manner, which includes a sustainability perspective.

It should be noted that the extended model for assessment of investments is intended to be used as an *extension* to the more traditional investment assessment methods. The extended model on its own would not provide enough information to base an informed investment decision upon.

6.3 Design criteria and constraints

After a series of discussions with both Tobias Ekberg of FM Global and Lars Stenblom of Trelleborg AB, it stands clear that in order to fulfil the purposes the model must allow ease of use and a straight forward assessment procedure that is transparent and not overly time consuming. That is, the model must be easy to understand and transparent in the sense that it allows personnel other than the one making the assessment to review how the assessment has been conducted. Furthermore, for the model to be useful for business management at all, it must be fast and easy to use as well as provide a brief and clear result that is easy to interpret. For this to be achievable the model is based on three main constraints:

1. The model will not include any monetary valuation of sustainability.
2. The model will be based on a general assumption of total impact elimination.
3. The model will use an ordinal assessment scale.

These constraints are further discussed in sections 6.3.1 and 6.3.2 below.

6.3.1 Exclusion of monetary valuation

The exclusion of any monetary valuation is a constraint that may be considered to make the assessment results more difficult to interpret. However, based on the fact that monetary valuation of social, environmental, and even some economic factors have previously been discussed to be very difficult to perform, the ease of use of the model would likely be severely reduced if an attempt to monetise the factors were included. Furthermore, as the extended model is intended to be used as an extension to other investment assessment methods the monetary aspects of an investment remains part of the overall assessment. Section 5.3 also concluded that the inclusion of sustainability aspects as a separate section in the investment decision process may be more effective than embedding the aspects into other assessment procedures. Combined, these facts make the use of the extended model as a non-monetary feature a reasonable approach.

6.3.2 Total impact elimination assumption

The model will essentially make an assessment of the impact from a potential fire. This means that the assessed fire protection measure, or combination of fire protection measures are assumed to completely eliminate the impact from the fire, or at least that the damage from a fire is reduced to a degree where it can be considered negligible. Thus, the benefit from the fire protection measure is equal to the expected impact from a fire if no fire protection measures were installed. Obviously this is quite a harsh assumption that implies certain constraints to the applicability of the model. This assumption is however considered reasonable since it makes the model significantly easier to use compared to if the reduction of the impact would need to be assessed in detail.

FM Global statistics show that 73 percent of industrial fires typically can be controlled by activation of nine sprinkler heads or less (FM Global, 2003). It is also widely known that adequately installed sprinkler systems provide high reliability and an effective means of limiting fire growth. On the basis of this, the total impact elimination assumption is probably reasonably valid for the majority of industrial fire situations. Though especially sensitive industries handling for example medical products or semi-conductors might at least from an economic point of view, incur significant damage even from very small fires. However, for small enterprises or for other fire protection measures such as smoke ventilation or passive systems the assumption might not be valid. If the model were to be used for assessment of such investments, close attention would need to be paid to the impact assessment procedure. Alternatively, the impact assessment made in this model could be only partially reduced by the fire protection measure. Thus, the benefit from the investment would be equal to the reduction of the impact that the investment is expected to give. Investigating how this could be assessed in detail is subject for a separate project and lay outside the scope of this thesis.

The conclusion from this is that the sustainability-extended investment assessment model will be valid for any situation where a fire protection measure, or combination of fire protection measures, can be considered to satisfy the assumption of total impact elimination.

6.3.3 Use of an ordinal assessment scale

The model uses an ordinal scale for assessment, which means it will only give results of the type "better than". I.e. the model will only determine which alternative is better than the other but not say anything about the absolute benefit or how much better one alternative is above the other alternatives. This is partly a consequence of not including monetary valuation of the assessed sustainability aspects, and is therefore also considered necessary to ensure that the model does not become overly complex in use. Furthermore, this is considered to add a value of flexibility to the model since each organisation themselves will have the opportunity to choose how much a certain benefit is worth in monetary terms. Altogether, the use of an ordinal assessment scale is considered to be a reasonable delimitation for the extended model for investment assessment in fire protection measures.

6.4 Model construction

The model is inspired by multi-attribute utility theory (MAUT) together with a simple profile chart. It uses the same decision objective layout as the MAUT, and produces a weighted score for each assessed investment alternative. The scores are similar to the profile chart based on grades of qualitative ordinal character.

Similar to the MAUT described in section 4.2.3, the extended model is built up on three levels of decision objectives. However, in this model the three levels are instead referred to as objectives, criteria, and attributes, with a hierarchical order according to Figure 19.

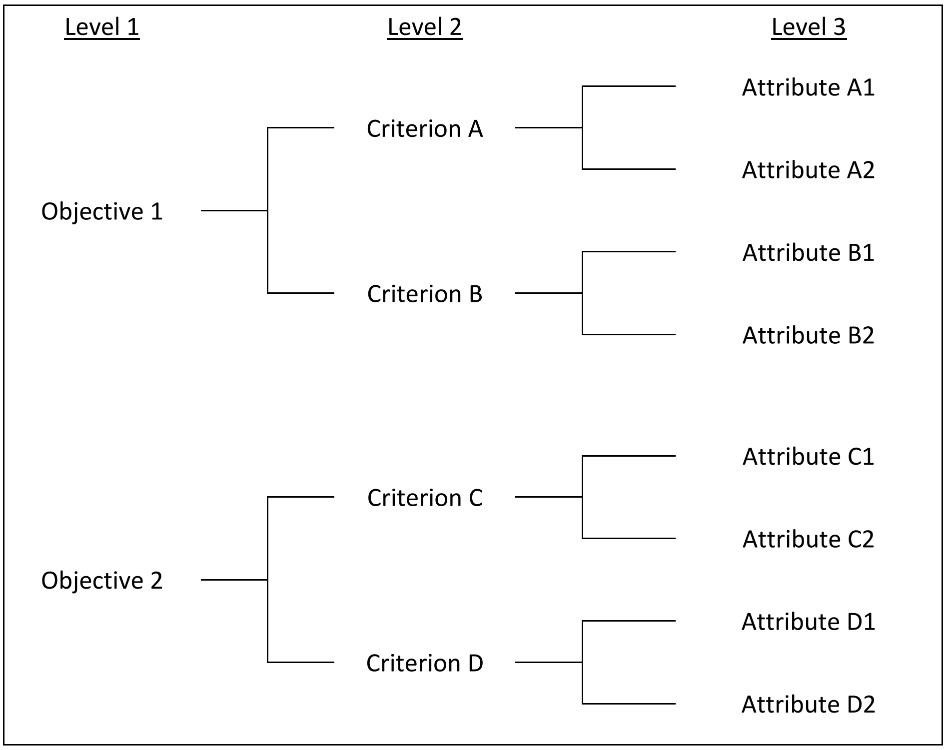
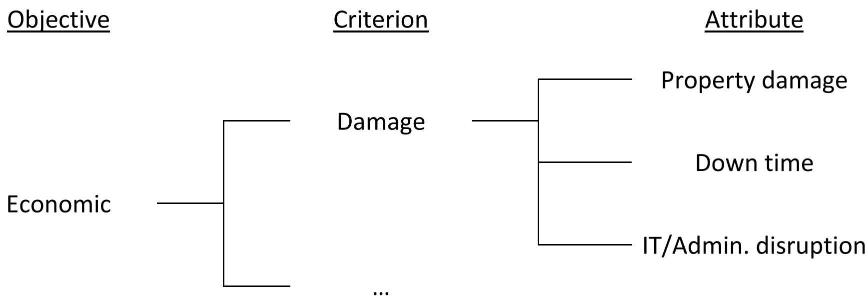


Figure 19: Hierarchical order of the extended investment assessment model.

The specific model developed in this thesis contains three objectives, namely economic, environmental, and social sustainability. Each objective is broken down into a number of criteria (normally three criteria for each objective). Each criterion is in turn compounded by a set of two or more attributes. An example using the economic objective could look like this:

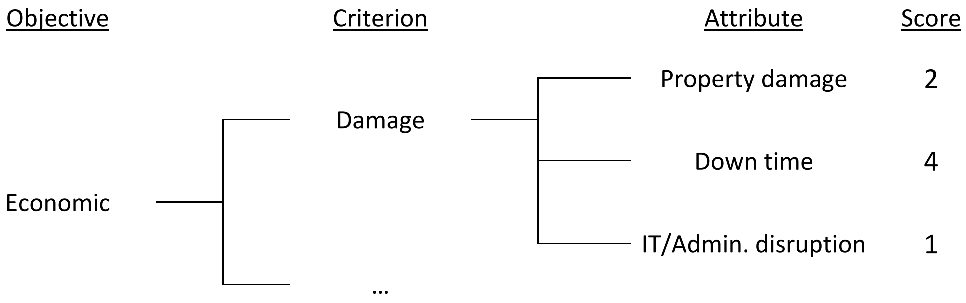


In the above example damage has been chosen as a criterion that is considered to be part of the economic objective. The damage criterion has in turn been broken down into the three attributes property damage, down time, and IT/administrative disruption. It is at the attribute level that the individual scoring is made (compare with the utility function of the MAUT in section 4.2.3).

As was noted in section 6.3, the model is essentially an impact assessment for a fire event. Therefore, the attributes is graded with regards to the expected impact an uncontrolled fire (not reduced by any fire protection measures) might have in the relevant setting. The attributes are given scores 1 to 4 where the grading is of the following character:

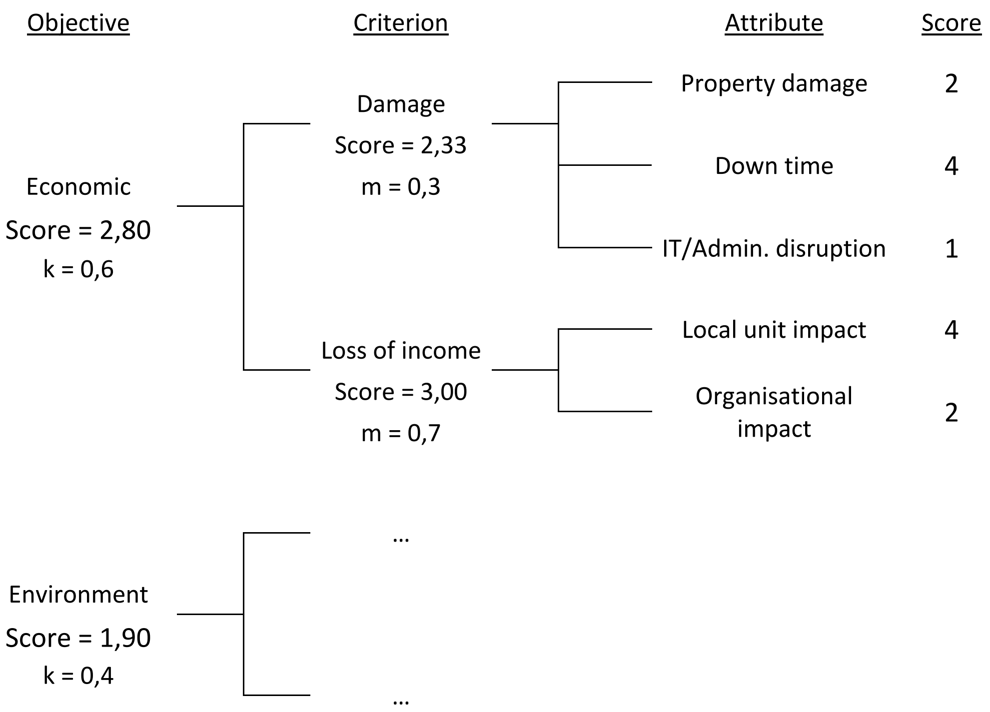
1. Insignificant impact
2. Minor impact
3. Significant impact
4. Major impact

Using the same economic example as above, say that a fire would generate a property damage that is considered relatively low, destroy a machine with long delivery time, and cause insignificant IT/administrative disruption. Then the scoring might be:



Different criteria might have different number of attributes. Thus, in order to make the scores comparable between different criteria, the attribute scores are used to calculate an average score that is transferred to the criterion level. i.e. in the example above the score for the damage criterion equates to approximately 2,33 since $(2+4+1)/3 \approx 2{,}33$.

At the criterion level, weights are assigned to reflect the relative importance of the different criteria within each objective. The weights at criterion level are denoted *m* (later also referred to as sub-weight). Likewise the objectives are also weighted in relation to each other. The weights at the objective level are denoted *k*. Thus, expanding the above example further we get:



For this specific example, a fire is expected to give a major impact on local unit loss of income, but the impact on the organisation as a whole is only considered minor. This gives an average score of 3 for the loss of income criterion. The decision maker has determined that for the economic objective the criterion *Loss of income* is more important than *Damage,* thus the weighting is 0,3 vs. 0,7 in favour for *Loss of income* (*m* weights). Using these weights an objective score can be calculated. In this example the score turns out to be 2,80 for the economic objective, since 0,3×2,33 + 0,7×3,00 ≈ 2,80.

The decision maker has determined the *Economic* objective to be more important than *Environment*, thus a weighting of 0,6 vs. 0,4 in favour for the *Economic* objective (*k* weights) has been chosen. Assuming that criteria and attributes results in an *Environment* score of 1,90 a total weighted assessment score can be calculated using the *k* weights. For this example the total weighted score is 0,6×2,80 + 0,4×1,90 ≈ 2,44.

On a general form the weighted *objective* score is calculated using the following equation:

$$Objective\ score = \sum\left(\frac{(\sum Attribute\ scores)_{cr}}{n_{cr}} \times m_{cr}\right)$$

Where: *cr* denotes a particular criterion
n_{cr} denotes the number of attributes included in the criterion *cr*; and
m_{cr} denotes the criterion weight for criterion *cr*.

Likewise the *total* weighted score can be calculated using the following equation:

$$Total\ score = \sum\left((Objective\ score)_{obj} \times k_{obj}\right)$$

Where: *obj* denotes a particular objective; and
k_{obj} denotes the objective weight for objective *obj*.

At this stage either the objective score or the total score can be compared to the assessment scale that was used for assessment of the attributes to determine how large the expected impact the assessed fire protection measure or combination of measures might have in a sustainability perspective. In the example above, the total weighted score equated to 2,44 which means that the total impact, and hence the expected benefit from the fire protection measure is somewhere between minor and significant (since a score of 2 means minor impact and a score of 3 means significant impact, refer page 74).

The model is summarised in an assessment sheet described in section 6.4.1.

6.4.1 Assessment sheet

The assessment is performed using an assessment sheet based on the layout shown in Figure 20. The alternatives (Alt. 1, Alt. 2 etc) are the different investment options being assessed. They can, for example, be different packages of fire protection measures being compared to each other, or they can be different buildings on a particular site, or different sites within a business group, being assessed in terms of where a fire protection investment would be most beneficial etc. It should be noted that as mentioned previously the model might not be valid for use with fire protection measures or combination of fire protection measures that do not satisfy the total impact elimination assumption (refer page 71). The final assessment sheet including an assessment instruction is presented in Appendix A.

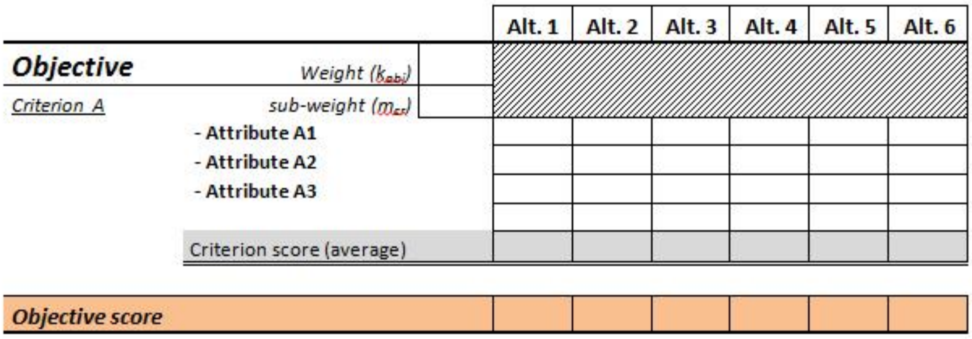


Figure 20: Assessment sheet layout.

6.4.2 Identification of decision criteria and attributes

Identifying decision criteria and attributes is indeed a challenging task. Sustainability exist in a variety of forms and determining which aspects that in the best way describes sustainability can therefore differ between various situations. Epstein and Wisner (2001) use the balanced scorecard, refined with a set of sustainability factors, to implement sustainability into general business management. As a set of measurable factors their examples are relatively straight forward, but trying to identify sustainability factors to be utilised specifically for the purpose of assessing investment in fire protection measures remains tricky. However, the selection of suitable decision criteria for the sustainability extended model developed in this thesis is inspired by the work of Epstein and Wisner. An important thing to note about this part of the model is that the suggested criteria could very well be modified to suit any organisations needs and desires. In fact, it is advocated that each company review and adjust the criteria as necessary to make them suitable for the particular company's own operations and interests. This is similar to what Epstein and Wisner (2001) promotes when using a balanced scorecard as a means of incorporating sustainability into business strategies; sustainability is defined differently by each organisation and the chosen sustainability indicators/factors should therefore be based on the organisations goals and strategy. The flexibility that this implies is one of the major strengths with the extended model for assessment of investments.

Table 6 outlines the decision criteria making up each objective in the sustainability-extended model. As was described in the previous section the criteria are broken down into a number of attributes, further discussed in section 6.4.3. Sustainability in general may include several different economic, environmental, and social factors. For the purpose of the sustainability-extended model the set of sustainability factors (criteria) have been chosen on the basis of items that might be of importance for an industrial company to consider in its risk management process.

Table 6: Assessment criteria grouped per objective.

Economic	Environment	Social
Damage	Air	Jobs
Loss of income	Soil/water	Health
Branding	Legal	

Damage and loss of income are criteria that obviously can be targeted in case of a disturbance. The branding criterion refers to anything that can be harmed in terms of trademark. Similarly, environmental impact in terms of air, soil, and water contamination are also quite obvious negative consequences that may occur from a fire event. The legal criterion refers to legal consequences that could be imposed on a company if it would cause an unacceptable environmental impact.

6.4.3 Assessment of attributes and weights

The assessment of how much a certain sustainability aspect (attribute) is impacted by the event of a fire requires participation and input by personnel who are well familiar with the organisation's needs and interests. A primary requirement in the model is also to assess weights. In order to perform this task the organisation must decide to what extent they are prepared to commit to the different dimensions of sustainability. Based on this, assessment of investment using the extended model is, like any other significant capital investment decision, most likely applicable at management level.

Similar to the criteria, the included attributes could, and should, be modified by the organisation so that it fits well with the organisations operations.

6.5 Use in context – evaluate – modify

The idea of this part of the design process is to evaluate how the model performs in its intended context and in relation to its stated purpose. Thereafter, any necessary modifications are made and the model will again be tested in its relevant context. The procedure continues in an iterative manner until the model performs as desired. (Abrahamsson, 2009)

Due to time limitations and the fact that the model development constitutes a limited portion of the thesis work, this part of the design process is not completed for the extended model for assessment of investment in fire protection measures. The model is instead evaluated according to the process described in Chapter 7. Continuous discussions with Tobias Ekberg of FM Global, and Lars Stenblom of Trelleborg AB have been an integral part of the model development work.

Chapter 7 – Model evaluation

As a means of verifying that the sustainability-extended model for assessment of investments in fire protection measures fulfils its intended purposes a simple evaluation is undertaken. This chapter presents the evaluation and its results as a whole.

7.1 Evaluation method

Many different methodologies for conducting evaluations exist. In both Backman (2008) and Höst et al. (2006) several general research methodologies are presented. Examples of methodologies are tests, experiments, interviews, questionnaires etc. Backman (2008) suggests a detailed presentation of the selected method including sections describing responders, material, and procedure. He also makes a note on the difference between qualitative and quantitative methods. For the purpose of this thesis, initially the idea was to make a reasonably extensive model evaluation looking at the differences in applicability between new and existing buildings, differences between companies who recently installed some form of fire protection and those who rejected the same, or letting evaluators apply the model to a predetermined investment situation. The extent of this thesis, however, does not allow for such thorough evaluations to be made, primarily due to time limitations. Furthermore, the evaluation preformed at this stage is made rather as a means of soliciting feedback on the form and features of the model, hence a deep and complex evaluation methodology is not considered necessary. Therefore, a simple questionnaire methodology is chosen and designed with inspiration from some of the general ideas found in Backman (2008) and Höst et al. (2006). As such, the evaluation is qualitative in character.

7.1.1 Responders, material, and procedure

The evaluation is designed primarily to investigate whether the stated model purposes are fulfilled. The responders of the evaluation are initially made up of a limited number of representatives from industrial companies found among the clients of FM Global's Swedish branch. Later personnel at FM Global are also invited to participate in the evaluation. In total approximately 10 responders are invited to take part in the evaluation.

All responders receive a letter instructing them to review a description of the sustainability-extended model for investment assessment and answer five questions in an appended questionnaire. The responders are asked to answer the questionnaire from the perspective of their professional role at their respective company, and return the questionnaires to the thesis author.

The questionnaire questions are of a qualitative nature. That is, they are formulated in a way that the responders can give their thoughts and comments on the design of the model. No strictly measurable or in other ways quantitative data can be retrieved from the evaluation.

The questions included in the questionnaire are outlined below. The material sent out to the responders is presented in its entirety in Appendix B.

Evaluation questions:

1. How well does the extended investment assessment model implement sustainability aspects into the investment assessment procedure for investments in fire protection measures?
2. Would the model be useful for assessment of investment within your organisation?
3. How well do the model's criteria and attributes represent sustainability in your opinion?
4. How well suited are the model's criteria with regards to the operations within your organisation?
5. What are the model's strengths and weaknesses? Would you like to add or take away anything from the model?

7.2 Results

Three filled out questionnaires were returned to the author. Even though this may be considered a limited material for an evaluation, it can at least provide an indication on the usefulness and applicability of the model.

The initial comments on the model are that it is relatively well described with clear purposes and structure. The scoring was considered to be functional and straightforward although it was noted that some people might want to use a more extensive scoring with up to seven grades instead of the provided four grades. One responder considered the model to incorporate sustainability quite well into the investment decision process for fire protection measures and that it would probably be easy to use for organisations where the management needs to be "convinced" into making investments of this kind. The same responder would not use the model on his own organisation but thought that the apparent flexibility of what features to include in the assessment provides a good representation of sustainability in general. Another responder thought that the model could very well be possible to use however not as a stand-alone assessment tool, since it lacks any type of quantification of the benefits. This responder also asked for a comment on how much better one result is above another (i.e. a cardinal scale).

Overall, the major strength with the model was considered to be its flexibility and versatility due to the possibility to manipulate the attributes and weightings according to the needs and preferences of an organisation. The major weaknesses with the model were considered to probably be the user themselves and that difficulties might exist in translating the organisation into suitable categories. A possible addition to the model could be the inclusion of a colour scheme to add a visual interpretation of the assessment result. It was also asked for some kind of note on what is a significant difference in the assessment results; increasing the total weighted score from 2.9 to 3.2, is that a small or large difference?

7.2.1 Comments on the evaluation results

From a general standpoint the evaluation result coincided relatively well with the author's expectations; that the model concept brings forward sustainability in the investment decision process even though it could use some modifications. The model seems to have reasonably well captured the essence of being flexible, easy to use and overseeing at the same time as it brings attention to sustainability aspects. One can also conclude that the model probably needs to be revised a number of times before it can be expected to become a final tool that is actually useful for an organisation. Given the amount of resources spent on developing the model, anything else would be surprising. The results also indicate that the evaluation failed to reflect some of the core purposes of the model and therefore leaves some comments to wish for. This is further discussed in section 7.3.

7.3 Discussion on the model evaluation

Even though the evaluation was deliberately limited in extent, a somewhat more extensive result would have been desired. As a means of indication on the performance of the model perhaps discussions during interviews rather than a questionnaire would have provided more useful results.

The timing of the evaluation send-out perhaps was not particularly suitable. With just a couple of weeks up to the Christmas holidays, receiving responses was difficult. If the evaluation would have been sent at a different time of the year maybe more responders would have participated. However, as was noted previously the evaluation was limited in extent and the received responses at least provided an indication of the model's performance. From this perspective the evaluation is considered to be reasonably sufficient.

The formulation of the evaluation questions could have been more thought through so that the results in a better way would reflect the model's performance in relation to its purposes. Question two was for example formulated as a "yes or no"-question without request for motivation. This meant that no explanations were given to why the model was or was not useful in the responder's organisation. Furthermore, since the questionnaire failed to reflect the model's performance in relation to for instance site-relative assessment within an organisation no conclusions on this could be extracted from the evaluation results.

The results from the evaluation are also dependent on how well familiar the responders are with the notion of sustainability and sustainable development. The documents included in the evaluation send-out only contained a brief background to the project and much of the deeper discussions made in this report were not included. Therefore, the evaluation questions that referred to how well sustainability was incorporated into the model and how well the included sustainability factors represented the responders' own organisation could have been difficult to answer. Perhaps should the evaluation send-out have included a richer sustainability description to better even out differences in prior knowledge among the responders? The evaluation send-out was however intentionally kept brief to not intimidate the responders from answering the questionnaire.

Chapter 8 – Conclusions

From the work presented in the thesis the following conclusions can be drawn:

- There is a need to increase the sustainability-thinking within the corporate world.
- Risk management in general, and fire protection in particular, inherently contribute to sustainability and sustainable development.
- Present tools for investment assessment are based on old-fashioned economic reasoning and do not account for sustainability in a desirable manner.
- Based on the previous points there are needs to develop the existing investment assessment tools to better represent sustainability.
- Primary difficulties exist in expressing sustainability in understandable and measurable terms, especially regarding investment assessment.
- The developed extended model for investment assessment raises awareness of sustainability, incorporates sustainability into the investment decision process, and accentuates the benefits from fire protection in a sustainability perspective.

The below sections outline somewhat deeper discussions on the conclusions.

8.1 The rising popularity of sustainability

Sustainability is understood in many different ways depending on who is talking about it. In this report two main perspectives have been presented; global and corporate. Even though sustainability at the basic level includes similar features regardless of the observed perspective, the actual implementation may differ. For instance, on a global scale sustainability serves to reduce the excessive consumption of natural resources. It strives to even out injustices and uneven distribution of the food supply among the world population, as well as reduce poverty. On a corporate scale, the same basic desires are key drivers, but the implementation is rather seen from a perspective that the business shall be kept alive. Of course, an ideal situation would be if each company would step up to their responsibility to care for the environment and societies surrounding their business activities. But to see this happen on a worldwide scale in the foreseeable future seems unlikely. However, corporations are starting to see that implementing and promoting sustainability is a strengthening commitment since the market, due to rising public awareness about sustainability issues, exercises an increasing pressure on the corporations. As such, being sustainable is contributing to competitive advantage which is a key incentive for business leaders. Thus, sustainability has simply become yet another aspect of enterprise risk management, essentially forcing corporations to consider sustainability issues whether they want to or not, in order to retain their place on the market. Adding to this the fact that risk management in general, and fire protection in particular, are inherently sustainable, investment in fire protection measures automatically enhances the organisations sustainability performance, and therefore also its competitive advantage. Pursuing sustainable development is good for the business, and good for all of its stakeholders.

8.2 The need for new methods for investment assessment

Current methods for investment assessment are based on old-fashioned economic theory, most of which originates from a time when the planet was seen as vastly limitless.

In relation to the number of people in the world and the level of technological development, this assumption was probably not completely wrong. At that time little was understood about how industrial activities could affect the surrounding nature and human beings. Nor were they aware of how the world population, and along with it the demand for food and other resources, was to grow inexorably. Today, the situation is a completely different one. The world population is large in relation to the production of, for instance, food around the planet. The technology has evolved tremendously, for good and for bad. We have come up with ways to produce more at a faster rate and we have moved into a time of many complex and intricate business supply chains with subsequent increasing dependencies and risks. Although investment assessment methods such as, for example, the net present value, allow the user to input sustainability related parameters into the analysis, this is unlikely to be done on a regular basis by business managers. Thus, there is most certainly a need to update the current investment assessment tools to better represent the emerging needs for sustainability considerations. Perhaps the need is a different one in general investment assessment, but for investments in fire protection measures, where estimation of the benefits is associated with major difficulties, a sustainability-extended assessment tool can be very useful.

8.3 The extended model for assessment of investments

Trying to incorporate sustainability into the investment decision process has proven to be an onerous task. Traditionally one would strive to use monetary terms to define all costs and benefits from an investment. However, adopting monetary valuation of sustainability aspects could very well be one of the most challenging tasks in business management. Who should decide how much it is worth to prevent one person from losing their job? On what grounds should such valuation be based? What is the ecological value of a cut down tree? And besides, what difference does it make on a global scale if a couple of square kilometres of forest are harvested to make room for new industries? How can the accumulated environmental impact from an organisation's activities be measured? And, how much does this impact cost? Obviously, answering questions of this character requires tremendous efforts from every one taking part in strategic business decisions. Trying to focus the sustainability thinking to those issues being affected or generated by fire leads one even deeper into the maze. However, given that fire protection inherently helps to increase sustainability, the inclusion of sustainability factors in the investment assessment procedure should logically also not be impossible. Through the developed extended model for assessment of investment in fire protection measures, the intrinsically sustainable features of fire protection can be accounted for. The model raises awareness of sustainability and provides an opportunity to include the same in the investment assessment procedure. The model on its own would unlikely provide enough information to make a final decision, but used in conjunction with other investment assessment methods the combined result may be useful for the organisation. Also, although the model provides an ordinal result, it may serve a noteworthy purpose in creating an appreciation of the organisation's risk profile that includes sustainability in a comparative manner. To be able to produce a model that is directly applicable in real investment situations would likely require additional efforts, but the model with its flexibility features could be a ground for the organisation to build further on.

8.4 Risk management and sustainability

The extended model for investment assessment is developed specifically for assessment of investment in fire protection measures in a corporate setting. An interesting question though is whether the model would be applicable to other types of risk management investments? On a fundamental level the model strives to be a source of information just as much as it provides a tool for structuring assessments. Therefore, one could certainly apply the model to a wider perspective of risk management. Perhaps it would need some modifications but then again flexibility is one of the model's primary strengths. The way the model was developed in this particular project made it include a set of constraints and limitations, such as for example the total impact elimination assumption. One implication of this is that the assumption must be applicable for the model to be valid. But on the other hand, one could very well change the meaning of this basic assumption. Say that one would be interested in assessing the sustainability benefit from a fire wall separating two important production facilities. Then for this particular assessment it might be applicable to assume that one side of the fire wall may be destroyed to some extent, but that the other side would be saved. Say that if the fire wall is not installed the fire damage would likely include large portions of both facilities. Then the impact of the fire, the one being set as equal to the benefit in the assessment, could comprise of the portion of the facility that would be saved (or lost if the fire wall is not in place). Then the model would be applicable only by changing the meaning of the total impact elimination assumption. The meaning of this in a wider perspective is that applicability of the model is primarily limited by the appreciation of the investment situation and the item to be protected. This also means that the model, even though it has not been tested for it, might be useful in all types of risk management. By changing the included sustainability factors as needed and perhaps also fine tuning the more basic functions, it may be applicable for virtually any situation.

As discussed in this report, risk management is an increasing field of interest at many levels around the globe. Likewise, the importance of sustainability is clearly increasing virtually everywhere. Given the apparent connections between these two subjects, used in combination they are bound to expedite development toward a better world. Here the model serves an important purpose to initiate a discussion about and around sustainability, and how the organisation through risk management can begin their journey toward more sustainable operations.

8.5 The way forward

Sustainability and all of its intricate relationships with risk management and investment assessment remains an elusive term. Given the trend of ever increasing focus on sustainability, the demand for further research is likely to increase as well. In particular, future attempts to quantify or in other ways translate sustainability into understandable and measurable terms would need some attention. This thesis can be seen as a first attempt to build an assessment tool that includes sustainability considerations in a structured manner, but significantly more time and effort must be spent in order to solve the very tricky issues that sustainability stands for. We are starting to see more and more organisations putting emphasis on sustainability related issues, which is indeed a welcome trend, but in order to even be *able* to achieve sustainable development on full scale, organisations must probably extend their interest in and efforts toward sustainability, ranging beyond financial performance.

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Appendix A

Sustainability-extended model for assessment of investments in fire protection measures

- Assessment sheet

This appendix contains the assessment sheet, divided into three sections according to the economic, environment, and social objectives respectively, that is used to perform the sustainability-extended assessment of investments in fire protection measures. Additional to the assessment sheet, an assessment instruction is also included.

Legend

The assessment sheet is based on a layout as shown in the below legend. The alternatives (Alt. 1, Alt.2 etc) are the different investment options being assessed. They can for example be different packages of fire protection measures being compared to each other, or they can be different buildings on a particular site, or different sites within a business group, being assessed in terms of where a fire protection investment would be most beneficial etc.

			Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
Objective	*Weight (k_{obj})*							
Criterion	*sub-weight (m_{cr})*							
	- Attribute A1							
	- Attribute A2							
	- Attribute A3							
	Criterion score (average)							
Objective score								

The final model's assessment sheet is presented on the following pages.

Assessment sheet

			Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
Economic	*Weight (k_{EC})*							
Damage	*sub-weight (m_D)*							
	- Property damage							
	- Downtime							
	- IT/administrative disruption							
	Criterion score (average)							
Loss of income	*sub-weight (m_L)*							
	- Local unit impact							
	- Organisation impact							
	Criterion score (average)							
Branding	*sub-weight (m_B)*							
	- Trademark							
	- Market share							
	- Shareholder impact							
	- Supplier impact							
	- Client impact							
	Criterion score (average)							
Economic score								

Environment	*Weight* (k_{EN})							
Air	*sub-weight* (m_A)							
	- Materials							
	- Transports							
	Criterion score (average)							
Soil/water	*sub-weight* (m_{SW})							
	- Chemicals on-site							
	- Location							
	- Ground surface							
	Criterion score (average)							
Legal	*sub-weight* (m_{Le})							
	- Remediation							
	- Fines							
	- Lawsuits							
	- Criminal offence							
	Criterion score (average)							
Environment score								
Social	*Weight* (k_{SO})							
Jobs	*sub-weight* (m_J)							
	- Lost jobs							
	- Local community impact							
	Criterion score (average)							
Health	*sub-weight* (m_H)							
	- Hazardous operation							
	- Employees exposed							
	- Employee stress							
	- Location relative to public							
	- Size of public population							
	Criterion score (average)							
Social score								
Total weighted score								

Assessment instruction

1. Determine the different *alternatives*. Then for each alternative:

2. Assign *objective weights* k_{obj} where *obj* denote the particular objective (economic, environment, and social respectively). Assigning weights is made by the user so that the weights correspond to the prioritisation that the organisation consider reasonable. All objective weights must summarise to 1.

3. Assign *sub-weights* m_{cr} where *cr* denote the particular criteria. Similar to the objective weights, assigning the criteria sub-weights is made at user discretion. All sub-weights must summarise to 1 within each objective.

4. Assess and grade the expected impact/benefit on all *attributes* for all criteria and objectives, using the below assessment scale:

   1 = Insignificant impact
   2 = Minor impact
   3 = Significant impact
   4 = Major impact

   Explanations to the attributes can be found in the *list of attributes* following on the next page.

5. Calculate *criterion scores,* by averaging the score for each criterion based on the attribute scores.

6. Calculate the *objective score by* multiplying the criteria average with the criteria sub-weight (m_{cr}) and adding the other weighted criterion averages within each objective.

7. Calculate the *total weighted score* by multiplying the objective score with the objective weight (k_{obj}) and adding all other weighted objective scores.

8. Finally the total weighted score or the weighted objective scores can be compared to the assessment scale to determine the qualitative level of benefit from the investment.

List of attributes

Economic

Damage	
- Property damage	How large is the expected property damage from a fire at the assessed unit?
- Downtime	What is the expected impact associated with down time due to repairs or rebuilding at after a building at the assessed unit?
- IT/administrative disruption	What impact on the organisation as a whole does an IT or Administrative systems disruption entail?
Loss of income	
- Local unit impact	How large impact in terms of loss of income may a fire have on the local unit (factory/building etc.)?
- Organisational impact	How large impact in terms of loss of income may a fire at the assessed unit have on the organisation as a whole?
Branding	
- Trademark	What impact may a fire in the assessed unit have on the organisation's trademark?
- Market share	Similar as above
- Shareholder impact	Similar as above
- Supplier impact	What supply chain impacts may a fire in the assessed unit have in terms of supplier impacts? (Those not included in shareholder impact above)
- Client impact	What supply chain impacts may a fire in the assessed unit have in terms of client impacts? (Those not included in shareholder impact above)

Environment

Air	
- Materials	To what extent does the building material and stored goods (including chemicals) impact on the emissions from a fire into the air?
- Transports	To what extent are the transports increased due to a fire? Both in terms of rebuilding and rerouting of normal production goods to/from alternative sites.
Soil/water	
- Chemicals on-site	To what extent are there chemicals on-site which in the case of a fire may lead to contamination of soil or water?
- Location	How is the location in relation to sensitive nature or water?
- Ground surface	How can the ground surface facilitate environmental impact from a fire in terms of spreading contaminated extinguishing water or leaking chemicals into the soil and/or close-by water? (Tarmac? Gravel/dirt? Sloping towards water? Etc.)

Legal	
- Remediation	What is the impact from costs associated with environmental sanitation due to leakage of chemicals or contaminated extinguishing water in to soil or water, following from fire damages?
- Fines	What is the impact in terms of fines due to environmental impact following from fire damages?
- Criminal offense	To what extent can environmental impact due to a fire at the assessed unit lead to legal repercussions in terms of criminal offense?
- Lawsuits	What is the impact in terms of lawsuits due to environmental impact following from fire damages?

<u>Social</u>

Jobs	
- Lost jobs	What is the impact in terms of lost jobs due to a fire?
- Local community impact	What is the impact on the local community due to lost jobs?
Health	
- Hazardous operation	What hazards exist within the operations at the unit? Rate in terms of impact if a fire occurs. It can be features that increase fire growth, cause explosions, create unusually toxic emissions or in other way can be a certain hazard to employees or public people during a fire.
- Employees exposed	How and to what extent are employees exposed to hazards such as above during a fire?
- Employee stress	To what extent can employees suffer increased stress levels during rebuilding after a fire incident?
- Location relative to public	How is the assessed unit's location in relation to the surrounding public community? Close or far away? Rate in terms of impact on the public.
- Size of public population	How large is the surrounding public which may be affected (in terms of health impact) by a fire at the assessed unit?

Appendix B

Sustainability-extended model for assessment of investments in fire protection measures

- Evaluation material

Robin Zetterlund 2010-12-14

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Evaluation of a sustainability-extended model for assessments of investments in fire protection measures

As a student at the Master of Science programme in Risk Management and Safety Engineering at Lund University, I am currently in the process of writing my final master's thesis with the title *Risk management and sustainability - Development of an extended model for assessment of investments in fire protection measures*. For this purpose I have together with Tobias Ekberg of FM Global initiated a project to look into how a sustainability concept could be incorporated into enterprise decision making. More specifically this refers to investigating the need for, and present an example of, an extended investment assessment methodology for investments in fire protection measures. For the interested, a slightly more detailed project background is appended at the end of this document.

A model has now been developed and by this letter I wish to kindly ask for your assistance in evaluating the model. Over the next couple of pages you will find a brief explanation of the model together with an instruction on how to use it. Following this, there is a questionaire with five questions to be answered. I understand that time is precious at this time of year but I estimate that this evaluation will take no longer than 30 minutes to complete, and the sooner I can receive a response the more thankful I will be.

I want you to read through the model purpose and description as well as the assessment instruction and answer the questions in the separate questionaire appended in the E-mail. More details can be found in the questionaire itself.

Many thanks for your participation!

Kind regards,
Robin Zetterlund

The sustainability-extended investment assessment model

Model purpose

The extended model for investment assessment is intended to bring attention to aspects of investments assessment that are traditionally not always considered in a structured manner. The model should make visible how fire protection inherently does add to the overall sustainability performance for the corporation. More specifically the model should strive to achieve the following purposes:

- Raise awareness at business management level that investments in fire protection measures entail benefits that range beyond financial performance, and that fire protection measures inherently provide a degree of sustainability.

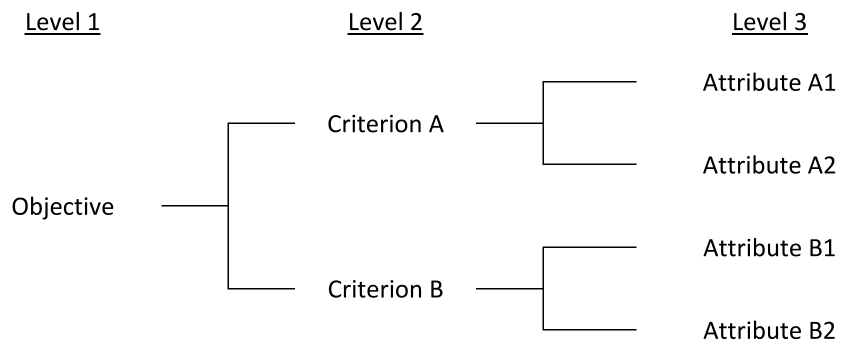
- Provide a tool for business management or equivalent to assess what impact a particular fire protection measure, or combination of fire protection measures, might have on sustainability performance factors.

- Provide a tool for business management or equivalent to assess which site or which building on a particular site where a fire protection measure would generate the highest benefit (prioritisation).

- Provide a tool for the already sustainability-minded organisation to assess fire protection investments in a structured manner, which includes a sustainability perspective.

Model description

The model is of a semi-quantitative nature since it calculates a weighted sustainability score by the use of a qualitative scoring of a number of attributes. That is, the attributes are given scores based on a qualitative scale, and mathematical operations are used to calculate a weighted score. The model includes three levels of decision objectives, specifically referred to as objective, criteria, and attribute in accordance with the figure below.

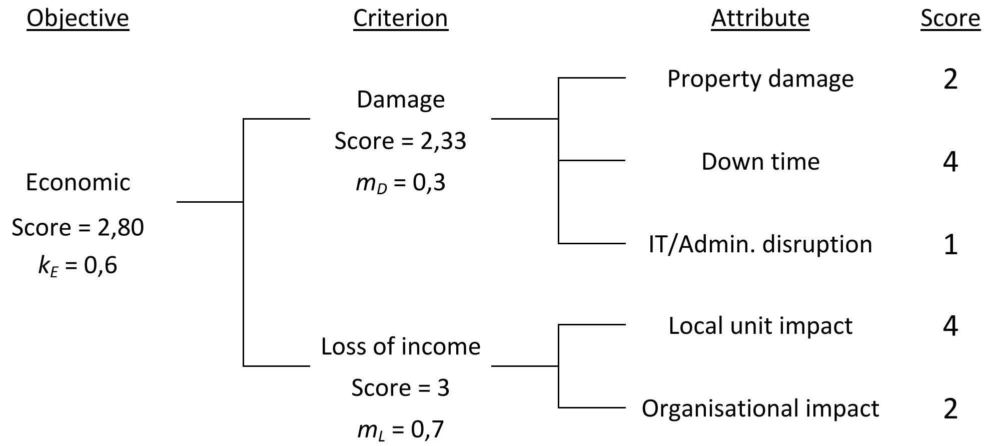


For this specific model the Level 1 objectives are Economic, Environment, and Social respectively. Each objective is broken down into a number of criteria (Level 2) which are considered to represent the objective. Each criterion is in turn compounded by a set of two or more attributes (Level 3) on which the assessment scoring is made.

The model is based on the assumption that the assessed fire protection measure, or combination of measures, in the case of a fire would reduce the fire consequences to a degree that they can effectively be considered negligible. Therefore, the model is essentially an impact assessment which for a specific building or site calculates the estimated impact from a fire without intervention by the fire protection measure being assessed. This calculated impact is then used as equivalent to the benefit the fire protection measure in question could provide. The attributes at Level 3 are given scores of 1 to 4 depending on the assessed impact a fire might have in regard to the specific attribute. The scoring is made according to the following qualitative scale:

1. Insignificant impact
2. Minor impact
3. Significant impact
4. Major impact

A criterion score is calculated by averaging the scores of the attributes. By using average scores at this stage all criteria are comparable regardless of how many attributes they are compounded by. The figure below shows an example of the scoring for the Economic objective.



Weighted objective scores can be calculated by using relative weights on the criteria level. That is, within each objective (Level 1) weights are assigned to the criteria (Level 2) to determine their relative importance in relation to each other. The criteria weights are also referred to as *sub-weights* and are denoted m_{cr} where *cr* represents the particular criterion. Similarly, the symbol k_E below the Economic objective denotes an objective weight, so that a total weighted sustainability score can be calculated. That is, all three objectives (Economic, Environment, and Social) are assigned a weight k_{obj}, where *obj* denote the particular objective, to determine their relative importance in relation to each other.

All criterion and objective weights are assigned at user discretion. Further, this model does not provide any monetary valuing of the assessed fire protection measures. Thus, the organisations using the model must themselves decide on the relative importance of the included factors as well as how much in monetary terms the benefits are worth.

The developed model includes a set of sustainability-related criteria and attribute. However, each organisation can develop their own criteria and attributes if necessary to better reflect the organisations operations.

The assessment is performed using a form based on the below layout (not included in this appendix, see note below). The alternatives (Alt. 1, Alt.2 etc) are the different investment options being assessed. They can for example be different packages of fire protection measures being compared to each other, or they can be different buildings on a particular site, or different sites within a business group, being assessed in terms of where a fire protection investment would be most beneficial etc.

The final assessment forms will follow on the next page. An assessment instruction is appended after the assessment forms.

NOTE: In order to reduce page numbers the layout example, assessment sheets, assessment instruction and list of attributes are not presented in Appendix B. However, these sections can be found in Appendix A, identical to how they were presented in the evaluation material.

Project background

Lately the term *sustainable development* (SD) has become increasingly popular in enterprise management. By one of its most frequently used ethical definitions sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Over the years the understanding of SD has evolved into comprising three dimensions, namely (1) economic, (2) environmental, and (3) social sustainability respectively; a concept that is sometimes referred to as the three pillars of sustainable development. Figure 1 shows one way to illustrate that these three sectors together make out the bearing foundation for achieving sustainable development.

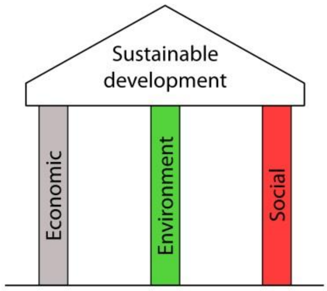


Figure 1: Three pillars of sustainable development.

The management of an organisation has a responsibility towards stakeholders to manage any risks that may threaten the company operations. As such, one might argue that risk management inherently provides qualities of a sustainable nature. For instance, fire protection (which is a form of risk management) and sustainability can be argued to share the common goal of making the world a better place, since fire protection strives to preserve and maintain. Risk reducing measures such as fire protection measures may entail significant capital investments, not always easily argued since they do not necessarily provide an obvious return on investment. However, even though the benefits from risk reducing measures such as for instance a sprinkler system may be hard to quantify, one can easily imagine those benefits if a fire incident actually were to occur. For instance, a sprinkler system, when activated, may prevent a fire from growing further or even reduce its size, this in turn likely means a lesser environmental impact from airborne particles or polluted extinguishing water contaminating the surrounding area. If the fire is limited the following business disruption is likely to be limited as well, with lesser economic impact on the company and maybe no need to lay off employees (social benefit). Thus, there are clear links between risk management, fire protection measures, and sustainability.

Recent research indicate that inclusion of sustainability factors (primarily environmental data) into the investment decision process might provide additional incentives to choose a certain investment option instead of another option where environmental data is not included. Implying that this is true, the willingness to accept a certain investment might increase if sustainability factors are included in the investment appraisal process. Therefore, it is interesting to investigate whether there is a need to develop further investment methods that includes additional assessment criteria to represent the benefits in a wider perspective; more specifically, a sustainability perspective. Stemming from this, a project has been initiated to investigate the need for, and present an example of, an extended investment assessment model that accounts for the impacts that fire protection measures might have on sustainability.

Evaluation questionnaire

After reviewing the model including its purpose, description, assessment instruction and list of attributes, please answer the following five questions from a professional point of view. That is, answer the questions on the basis of how the model would perform in an investment situation in the organisation you work within. Answers can be written directly in this word document, saved with a new file name and returned by E-mail. You may also print and write by hand (please write clearly) and either scan and return by E-mail or send by regular post. You may also simply write the answers directly in an E-mail. Return your answers to one of the following addresses:

By E-mail to: [redacted]

By regular post to: [redacted]

Evaluation questions:

1. How well does the extended investment assessment model implement sustainability aspects into the investment assessment procedure for investments in fire protection measures?

2. Would the model be useful for assessment of investment within your organisation?

3. How well do the model's criteria and attributes represent sustainability in your opinion?

4. How well suited are the model's criteria with regards to the operations within your organisation?

5. What are the model's strengths and weaknesses? Would you like to add or take away anything from the model?

Other comments:

Thank you for your participation!