CHALMERS

Assessment of alternatives of urban brownfield regeneration, using SCORE tool

Contribution to application of SCORE in early stages

Master of Science Thesis in the Master's Programme Infrastructure and Environmental Engineering

- Preliminary version (2014) -

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CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2015
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ABSTRACT

SCORE is a multi-criteria analysis tool that combines a cost-benefit analysis (CBA) and a semi-quantitative evaluation of environmental and social effects. Nowadays, the scope of application of SCORE tool is the assessment of alternatives of remediation, close to the project level, when quite a lot of information is already available, and probably different experts take part of the process. Therefore, applying the tool in different context needs to be done with care.

In the context of the research project Balance 4P, SCORE tool is applied to a case-study of urban brownfield redevelopment in an early stage, Fixfabriken site, located in Göteborg.

Thereafter, contributions to further application of SCORE to these specific early stages are made. Suggestions are mainly focus on considering additional cost and benefit items, and on replacing the CBA by a semi-quantitative assessment. Further work is necessary to evaluate these possibilities.

Key words: alternatives; urban brownfield regeneration / redevelopment; sustainability; assessment; cost-benefit analysis; multi-criteria analysis; SCORE; Balance 4P.

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Acronyms

Balance 4P – research project “Balancing decisions for urban brownfield regeneration - people, planet, profit and processes”

CBA – cost-benefit analysis

KM – känsliga markanvändningar (sensitive uses)

MCA / MCDA – multi-criteria analysis / multi-criteria decision analysis

MKM – mindre känsliga markanvändning (less sensitive uses)

NPV – net present value

PAH - Polycyclic aromatic hydrocarbons

SADA - Spatial Analysis and Decision Assistance

SCORE - Sustainable Choice Of REmediation

SEPA – Swedish Environmental Protection Agency

TCE - trichloroethylene

1 Introduction

This chapter provides the background to the thesis, presents the aim and objectives as well as delimits the scope of the work, introduces to the method and systematize the structure of the report.

1.1 Background

Urban development and urban regeneration are necessary now and in the coming years, all over the globe. On one hand, world population has been growing and it is expected that more and more people will live in urban areas. On the other hand, there is lack of space in the urban environment, and there has been misuse of areas inside or in the vicinity of cities, due to former or current activities that in a way or another have negative impacts on the welfare of the local communities and on the environment. These are often called urban brownfield areas, which quite often are contaminated, leading to an increase of the costs with urban regeneration. A cautious approach is advisable and limited budgets can be a barrier to undertake the desirable actions. Moreover, different stakeholders with diverse interests make, quite often, the planning and decision-making processes even more complex. For these and other reasons, it is necessary to find adequate and liable solutions, considering the three domains of sustainability, namely economic, social and environmental ones. To deal with this, studies to support decision-making need to be done and to have a scope and level of detail adequate to the stage of planning or implementation of each project, otherwise less supported decisions will be made, thus affecting resources in an improper way.

Quite often, redevelopment of brownfield sites has remediation as a major part of the interventions. Therefore, a holistic perspective including all the works and assessing its effects on economic, environmental and social domains should be part of the process. It has also been shown that more efficient and sustainable solutions are likely to be achieved in earlier stages of the planning process.

Worldwide, several tools are available and have been developed and used to assess sustainability at different stages of the planning and implementation process of urban development including remediation, to serve the purpose of supporting sustainable decision-making. These tools may include environmental impact assessment of plans, programs and projects; cost-benefit analysis; multi-criteria analysis; among others. Specific tools applicable to contaminated sites and urban brownfield areas have also been developed or tested.

1.2 Aim & Objectives

The aim of this master thesis is to apply to a new context a tool, named SCORE - Sustainable Choice Of REmediation, which so far has been applied to assess the sustainability of alternatives in remediation projects in contaminated sites. The new situation is a process of redevelopment of an urban brownfield site in a much earlier stage, considering alternatives of both different remediation approaches and future land uses.

Based on the experience of applying the tool, the goal is to contribute to the adjustment of the SCORE tool, thus enabling its use to similar processes as the case-study, at early stages of the planning process.

The work is part of the research project “Balance 4P - Balancing decisions for urban brownfield regeneration - people, planet, profit and processes”, where one of potential tools is applied to a specific case-study of the project, a brownfield area located in the city of Gothenburg, Sweden.

In order to fulfil the overall objective, the main tasks included are the following:

- Characterization of the Fixfabriken site, regarding its natural conditions, anthropogenic use and environmental contamination.
- Generation of alternatives in the site, which include different options of soil remediation and of urban regeneration;
- Performance of a CBA, to assess the social profitability of the alternatives;
- Assessment of the sustainability of the alternatives, by integrating economic, environmental and social domains in the SCORE tool;
- Suggestions of improvements and adjustments to the SCORE tool to enable application of SCORE to urban redevelopment in early stages of the planning process.

1.3 Scope

This master thesis is focus on one assessment tool, SCORE, and one case-study, Fixfabriken site.

For remedial strategies and land use a limited number of alternatives are considered, and assessed based on the information available until August 2014. More recent data of the local conditions are not included.

It is documented that SCORE has been designed and used to remediation projects, and that is not tailed to be used to land-use planning processes. The contributions to eventually use the tool to similar process of the case-study assessed are mainly explorative and require further investigation, development, implementation and testing, which is out of the scope of this thesis. Furthermore, the suggestions are focus on the economic domain.

1.4 Method

The literature review includes scientific articles, technical books and reports. Due to the connection of this work to Balance 4P research project and SCORE-tool, specific literature and experiences will be also considered.

Characterization of the Fixfabriken site is based on: visit to the site; site specific data from technical reports, maps and interviews with experts in soil contamination and in the archaeological domain.

Selection of alternatives is mainly based on stakeholder’s preferences (surveys and interviews) and on the local conditions of the site. The method assumes an iterative process, with new alternatives being generated whenever previous ones are assessed in as not sustainable.

Assessment of the economic domain of the alternatives of remediation and redevelopment of the site is performed through a Cost-Benefit Analysis. Different benefit and cost items are monetized and expressed in Net Present Value (NPV), thus calculating the social profitability of the different alternatives. The SCORE tool is used to identify the items to consider, and a previous master thesis where an initial version of the tool was used to a different case-study, is a support for some of the specific methodologies to monetize cost and benefit items. The specific methods to each of the monetized items are described in appendices.

The excel-based SCORE tool supports the calculation of the NPV of each item per alternative and of the social profitability per alternative.

In order to evaluate the sustainability of the alternatives, a qualitative assessment of the environmental and social domains is done in close collaboration with researchers from Chalmers University of Technology, who are part of the Balance 4P project. When integrating the three domains, a final result allows assessing the alternatives as sustainable or non-sustainable. Uncertainties are calculated based on Monte Carlo simulation method.

Limitations on the application of this methodology to regeneration of urban brownfield areas in early stages of the planning process are identified based on feedback from the stakeholders, and on the experience and difficulties felt when performing the assessment using the SCORE tool. This supports the need to consider different types of improvements or adjustments in the tool.

1.5 Structure of the report

This Master thesis begins with an introductory chapter (**Chapter 1**) contextualizing the subject of urban brownfield regeneration and how the work included in the thesis embraces this issue. **Chapter 2** provides a general view of how the subject has been considered, namely projects and tools addressing the subject, as well as key-concepts on this.

Chapter 3 presents the method used in this master thesis. An introduction to the working process is followed by a concise theoretical description of MCA as decision-support tool in sustainability and a more detailed description of the SCORE tool that supported the work done in the thesis.

Chapter 4 addresses the case-study conditions, namely the natural ones and the present land uses and diverse constraints to future development. **Chapter 5** identifies and describes the reference alternative and some of the possible future alternatives of remediation and redevelopment of the case-study site, conceptualized during this master thesis. From the process of identifying, selecting and rejecting alternatives, two sets of alternatives, in a total of ten alternatives are therefore established to further assessment. **Chapter 6** is focus on the application of the SCORE tool, on the detailed description of the CBA performed and concise information of the assessment made of the environmental and social domains. Results considering the uncertainty and sensitivity analysis are presented.

Chapter 7 discusses how the case-study was conducted and how the SCORE tool performed. The feedback from the application of the tool to the case-study is highlighted. The chapter continues suggesting adjustments to the tool in order to allow its application to process of urban brownfield redevelopment in early stages. **Chapter 8** concludes and provides recommendations.

Appendices complement the main text of the report, providing detailed information on the CBA, and additional information on the assessment of environmental and social domains.

2 Urban Brownfield Regeneration

This chapter presents a short review of some key-concepts in urban brownfield regeneration. Furthermore, an idea of the diversity of platforms that have been focusing on this field, and some of the instruments, tools and methods that are available is given. Specific information is provided to project Balance 4P and to SCORE tool, the last in a separated chapter.

2.1 Key Concepts

Several basic but key concepts need to be pointed out, namely, brownfield, regeneration / redevelopment / revitalization, and sustainable development.

The definition of **brownfield** areas varies across the world and even in Europe. Based on different concepts from European countries, the Concerted Action on Brownfield and Economic Regeneration Network, which also stands for CABERNET, defines brownfields as areas that '*have been affected by the former uses of the site and surrounding land; are derelict and underused; may have real or perceived contamination problems; are mainly in developed urban areas; and require intervention to bring them back to beneficial use*' (CABERNET Coordination Team, 2006).

Different terms appear connected to the improvement of the environmental state of brownfield areas and in its use, namely **redevelopment**, **regeneration** and **revitalization**, which quite often also include remedial actions. The literature is not very clear about the difference between these concepts.

Brundtland Commission initially defined **sustainable development** as the '*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*' (World Commission on Environment and Development, 1987).

Redevelopment of urban **brownfields** allows containing and reverting eventual contamination problems, take advantage of existing land already up taken and artificialized, thus reducing the urban sprawl and the need to uptake new areas in the surroundings that can be left untouched or to other purposes. Tools that enhance the benefits of the process and lead to sustainable choices towards a **sustainable development** of the urban areas and surroundings should support the redevelopment initiatives and the decision process. Robust and integrated decision-making is necessary when it comes to regeneration of brownfield areas (S.J.T. Pollard, 2004).

2.2 Networks and projects

Due to the relevance of the subject, different **research networks / platforms** and **projects** have been focusing to a higher or lower extent on brownfields, namely the European ones or based in one European country: BERI - Brownfield European Regenerative Initiative, CABERNET - Concerted Action on Brownfield and Economic Regeneration Network, CLARINET - Contaminated Land Rehabilitation Network for Environmental Technologies, COBRAMAN - Manager Coordinating Brownfield Redevelopment Activities, EUBRA - European Brownfield Revitalisation platform, EUGRIS - European Groundwater and Contaminated Land Remediation

Information System, LUDA - Improving the quality of life in Large Urban Distressed Areas, MAGIC - Management of Groundwater at Industrially Contaminated Areas, Brownfield Working Group integrated in NICOLE - Network for Industrially Contaminated Land In Europe, NORISC - Network Oriented Risk-assessment by In-situ Screening of Contaminated sites, PROSIDE - Promoting Sustainable Inner Urban Development, REFINA - Research for the Reduction of Land Consumption and for Sustainable Land Management, REKULA - Restructuring Cultural Landscapes, RESCUE - Regeneration of European Sites in Cities and Urban Environments, REVIT - Revitalising Industrial Sites, SUBR:IM - Sustainable Brownfield Regeneration: Integrated Management (NICOLE Brownfield Working Group, 2011) (COBRAMAN, 2009), SuRF – Sustainable Remediation Forum UK, TIMBRE - Tailored Improvement of Brownfield Regeneration in Europe, HOMBRE - Holistic Management of Brownfield Regeneration, and, more recently, BALANCE 4P - Balancing decisions for urban brownfield regeneration - people, planet, profit and processes (Kok, 2014).

BALANCE 4P research project has the overall aim of "*deliver a holistic approach that supports sustainable urban renewal through the redevelopment of contaminated land and underused sites*" (Chalmers University of Technology, 2013). In the project partners from four European countries are collaborating towards specific objectives, including:

> "*1) application and assessment of methods for design of land redevelopment strategies for brownfields that embrace the case-specific opportunities and challenges;*
>
> *2) development of a method for sustainability assessment of alternative land redevelopment strategies to evaluate and compare the ecological, economic and social impacts of land use change and remedial technologies; and*
>
> *3) development of a practice for redevelopment of contaminated land in rules and regulations to enable implementations.*" (SNOWMAN NETWORK Knowledge for Sustainable Soils, 2013) (Chalmers University of Technology, 2013).

For more general information on the project, see Chalmers University of Technology (2013) and SNOWMAN NETWORK Knowledge fos Sustainable Soils (2013).

Within the project, three case-studies are developed, one of them being Fixfabriken, in Göteborg, Sweden.

2.3 Instruments, tools and methods

For **urban development and redevelopment** in general, it is worthwhile to consider the Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001, on the assessment of the effects of certain plans and programmes on the environment, also known as "SEA" Directive for "Strategic Environmental Assessment" (European Commission, 2014), which applies to all plans and programmes that set a framework for future development of the projects listed in Annexes I and II of the Directives on the assessment of the effects of certain public and private projects on the environment (European Commission, 2014). To highlight that Annex II, b) includes projects as "Urban development projects, including the construction of shopping centres and car parks".

Identification of tools considered useful when proceeding with brownfield redevelopment is provided by COBRAMAN (2009). Kok also presents an extensive overview of instruments, tools or methods developed and applied in Europe, suggesting that can be applied in brownfield redevelopment (Kok, 2014).

Specifically, the research project Balance 4P tested already tools / methods to generate and to assess redevelopment alternatives in urban brownfields. To generate alternatives, stakeholder consultation and SEES-tool (System Exploration of Ecosystems and Subsurface) have already been used. To assess alternatives, qualitative Social Impact Analysis (SIA), Semi-quantitative mapping of changes in Ecosystem Services (ESS), CBA and MCA tools have already been used and within the timeframe of the research project, published.

Examples of other tools applied by other authors are CO_2 calculator, Sustainable Remediation Tool (SRT), Risk Reduction, Environmental Merit and Costs (REC) and GoldSET (Beames, Broekx, Lookman, Touchant, & Seuntjens, 2014).

When considering tools to assess sustainability applied to the **stage of remediation**, stage that is often necessary for improvement of brownfield areas, several tools have been developed and tested, namely: Environmental risk assessment, Environmental (impact) assessment, Social impact assessment, Health impact assessment, Cost-benefit analysis, Multi-criteria analysis (MCA) and multi-attribute techniques (MAT), Life cycle analysis (LCA), Sustainability appraisal, Stakeholder analysis, Engagement techniques (S.J.T. Pollard, 2004). Other forums identify the mentioned and additional ones, focusing on carbon metrics, efficiency performance evaluation, risk assessment, traditional environmental impact assessment and strategic environmental assessment, among others (SuRF - Sustainable Remediation Forum UK, 2010).

Some of the specific tools are: in MCA tools, SCORE (Lars Rosen, 2013) SAMLA for contaminated sites (SGI Statens Geotekniska Institut, 2014) and Flandres MCA for BATNEEC, that include environmental, technical and financial aspects; in Life cycle-based evaluation methods, REC-risk reduction, environmental merit and costs is a possibility (Cappuyns, 2013); in Carbon footprint calculator - CO_2 calculator, the Swedish Carbon footprint calculator to remedial actions (Svenska Geotekniska Föreningen, 2014), Soil remediation tool (SRT), SiteWiseTMTool and Tauw Co2 calculator are available (Cappuyns, 2013).

3 Method

This chapter clarifies the working process followed, as well as describes the tool to support decision-making SCORE and its theoretical background.

3.1 Working process

The main methodological steps are shown in Figure 3-1. The diagram in the middle includes the several steps undertaken. Tasks within boxes in grey and bold are the ones done by the author, whereas the ones in light grey correspond to tasks shared between the author and the research project members from Balance 4P. The tasks within the white boxes are the ones where the intervention of the author was by far less relevant. On the left side, the timeframe clarifies that the thesis took place between June and December 2014. On the right side, the interveners are identified shortly.

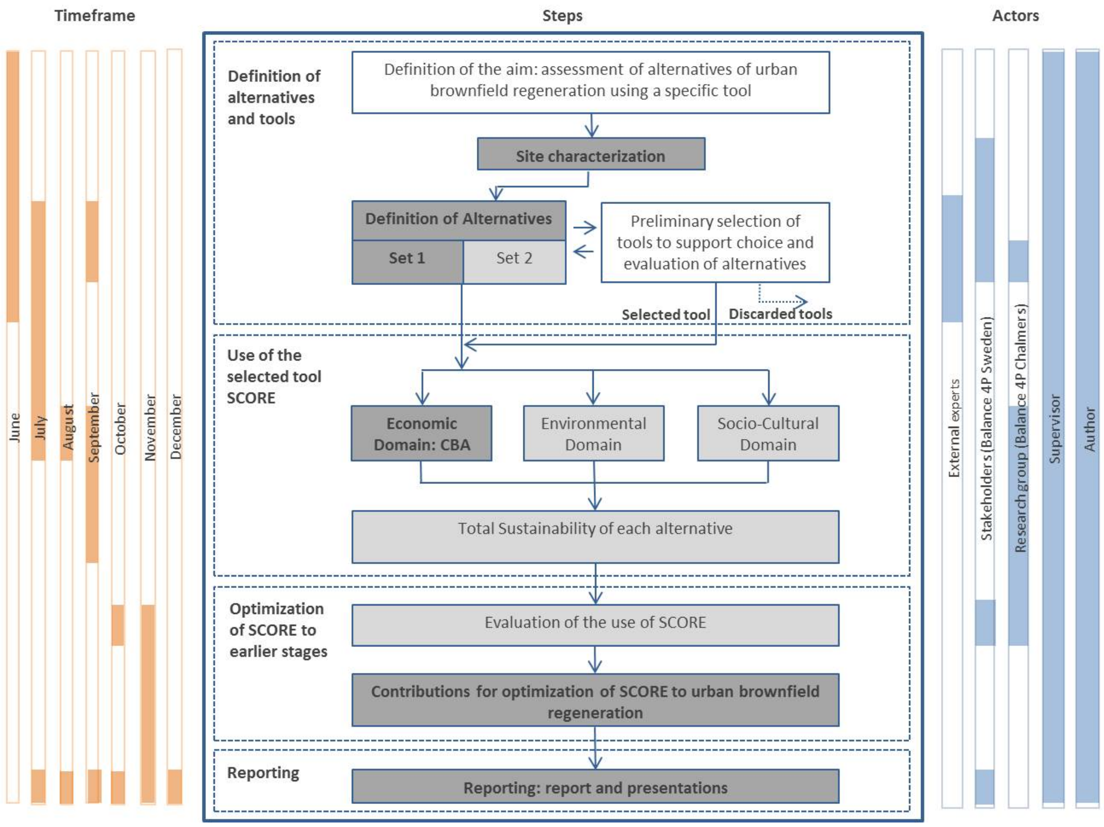


Figure 3-1 Working process, considering the timeframe, steps and actors involved (own illustration).

Specific methods were used along the work. SCORE is described in the next section and sub-methods used when assessing the economic domain are presented in the appendices.

3.2 SCORE Multi-Criteria Analysis based tool

Multi-criteria analysis (MCA) has been used to support environmental decision-making and sustainability assessment. By applying a MCA, the degree to which a project fulfils a set of performance criteria is assessed. Both qualitative and quantitative information are possible to be integrated in a MCA. On the other hand, MCA methods include qualitative, semi-quantitative and quantitative approaches. When numerical values are attributed as scores and weights of criteria, multi-criteria decision analysis (MCDA) designation is often used. ((Rosén, o.a., Manuscript submtitted (2014)) in (VOLCHKO, THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY. Assessing Soil Functions for Sustainable Remediation of Contaminated Sites, 2014)).

SCORE (Sustainable Choice of REmediation) is a MCDA tool designed and used specifically to sustainability assessment of remedial actions and support to decision-making.

As described in Rosén (2009, 2013 and 2014), SCORE is designed to provide decision support when choosing between a set of remediation alternatives, where:

- remediation alternatives are assessed against a reference alternative;
- the assessment is based on the how each alternative performs in the key criteria in the economic, environmental and social domains;
- qualitative and quantitative estimations of criteria are integrated;
- scorings are used in the environmental and social domains, whereas quantifications of monetary costs and benefits are considered in the economic domain;
- scorings and quantifications of the criteria and the relative importance (weights) of these criteria are taken into account to calculate a normalized score for each alternative, by using a linear additive approach;
- compensation between different components of the system (both sustainability domain and criteria levels) is considered in the assessment, leading to classification of the alternatives as having a weak or strong sustainability;
- a full uncertainty analysis of the results, using Monte Carlo simulation, is provided, same as a sensitivity analyses of the outcomes.
- the structure allows preferences and opinions of involved stakeholders to be openly integrated into the analysis, by means of weighting of sustainability domains and criteria.

More detailed information about SCORE framework and conceptual model, key performance criteria, in particular to economic domain, sustainability assessment, uncertainty and current practice are further on provided. Additional information can be obtained in Rosén (2009), Rosén (2013), Rosén (2014) included in Vochko (2014), and Söderqvist (2014) included in Brinkhoff (2014).

3.2.1 SCORE framework and conceptual model

SCORE decision support framework in Figure 3-2, is focus on providing support to decision-making by comparing the performance of a set of remediation projects alternatives against a reference alternative.

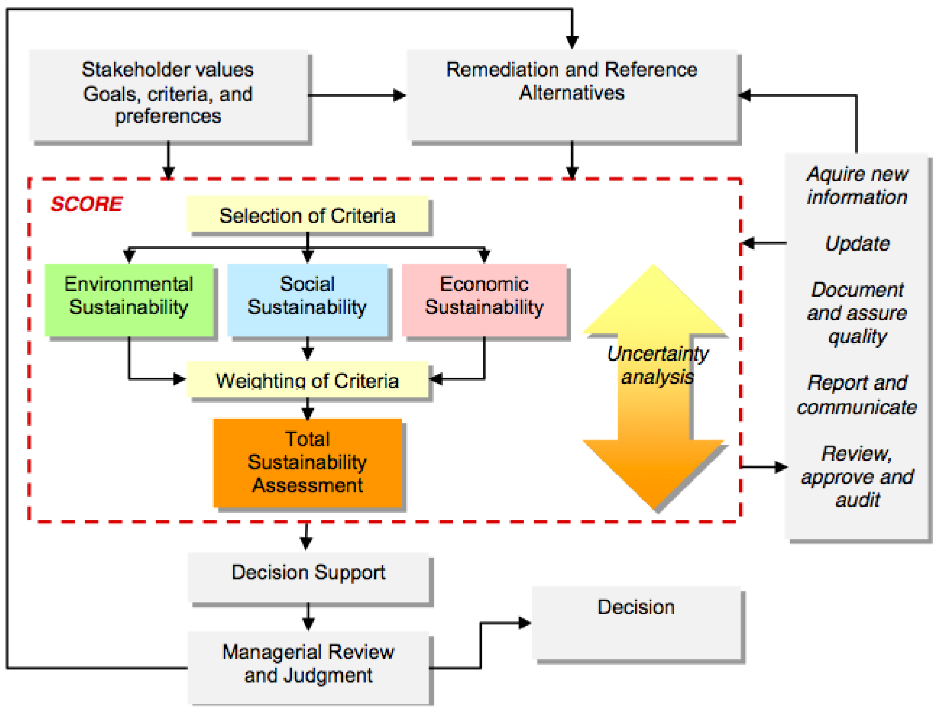


Figure 3-2 The SCORE decision support framework, in Rosén (2014) included in Vochko (2014).

For detailed explanation of the framework, see Rosén (2014) included in Vochko (2014).

The **conceptual model of SCORE**, represented in Figure 3-3, is based on the cause-effect chain concept that is commonly used in risk assessment.

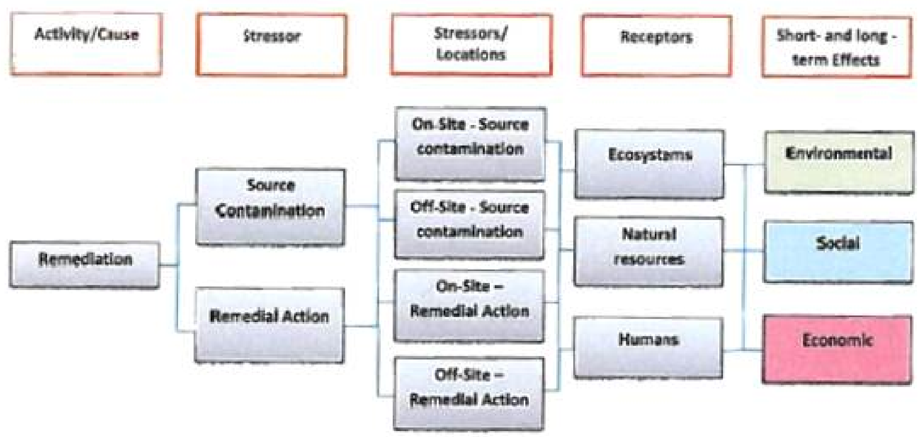


Figure 3-3 The SCORE conceptual model, in Rosén (2014) included in Vochko (2014).

The cause of the effects is the remediation action at a particular site; the main stressors are the change in the source contamination and the occurrence of the remedial action; their effects can happen at different locations, on-site and / or off-site; the receptors that can be affected by the effects of the remediation are ecosystems, humans and / or natural resources; long and short term effects include environmental, social and economic ones.

3.2.2 Key performance criteria

Key performance criteria for each sustainability domain that are capable of representing all key sustainability aspects and avoid double-counting of effects have been identified as explained in Brinkhoff (2014) and are presented in Table 3-1.

Table 3-1 – Key-criteria in the social assessment of SCORE, in Rosén (2014) included in Vochko (2014).

Environmental domain	Social domain	Economic domain
• Soil • Flora and fauna • Groundwater • Surface water • Sediment • Air • Non-renewable natural resources • Non-recyclable waste	• Local environmental quality and amenity • Cultural heritage • Equity • Health and safety • Local participation • Local acceptance	• Social profitability

Environmental domain comprises eight key criteria and **social domain** includes six. Recently, a specific tool was developed to assess the key performance criteria Soil of the environmental domain, see Volchko (2014).

An explanation of each key criteria in the environmental and social domains, as well as the identification of the sub-criteria are available, see Rosén (2014) included in Vochko (2014).

Economic domain includes one key performance criterion, the social profitability, which is obtained by performing a cost-benefit analysis (CBA), preceded by the identification and preliminary assessment of which ones to monetize.

Within the CBA, positive and negative consequences of the alternatives are expressed in monetary terms, respectively as benefits (Bi) and costs (Ci), considering a certain time horizon (T) during which a certain effect last, and a selected social discount rate (r). The monetization of each benefit and cost item is expressed in present value (PV), and then the Net Present Value (NPV) is calculated, see Equation … (Söderqvist, 2014 in Brinkhoff, 2014).

NPV = … (Eq. …)

PV(Bi) = …. PV(Ci) =…

NPV=…PV(Bi) -…PV(Ci)

NPV, the sum of all the benefits and costs inform on if an alternative entails a positive or a negative social profitability, respectively if the sum is positive or negative. For a complete description, see Söderqvist (2014) in Brinkhoff (2014).

Four main benefits and four main costs, each of them with sub-items, are part of SCORE to assess the key performance criteria of the economic domain. To see the sub-items of each main cost and benefit items, as well as its description, see Söderqvist (2014) in Brinkhoff (2014). Recently, a specific tool was developed to assess one of the specific cost sub-items, the Project risks one. Detailed information on this is available in Brinkhoff (2014).

3.2.3 Sustainability assessment process

Before starting the MCDA, alternatives complying with constraints such as time, budget, technical feasibility, legal aspects, and public acceptability, are defined, as well as the reference alternative. The SCORE assessment follows several main steps.

In **selection of criteria**, key criteria and sub-criteria from environmental and social domains are selected for consideration in the assessment. In economic domain, benefits and costs expected to be relevant are included to be monetized. Eventual exclusion of criteria or cost-benefit items from the assessment must be clearly motivated.

A semi-quantitative (ordinal) **performance scale** is used when scoring the effects in the environmental and social domains. By using a guidance matrix for each criterion, one of the following levels are assigned: Very positive effect: +6 to +10; Positive effect: +1 to +5; No effect: 0; Negative effect: -1 to -5; Very negative effect: -6 to -10. A short motivation for the score chosen needs to be done, contributing to a higher transparency of the assessment of these two domains. The scorings are subjective and are based on available data, expert judgment, questionnaires and interviews.

The items of the economic domain classified as relevant should be monetized as much as possible. The relevant items not able to monetize need to be assessed qualitatively as very important or somewhat important items, and further on included in a qualitative discussion concerning not quantifiable items.

Weighting of criteria and sub-criteria of the environmental and social domains is attributed with respect to their relative importance.

To each domain, a **sustainability index** is calculated for each alternative, which follows a simple linear additive approach. For a complete description of the process, see Rosén (2014) in Vochko (2014).

A **normalized sustainability SCORE** is calculated for each alternative taking into account the three domains, namely the environmental sustainability score, the social score and the economic sustainability (NPV). The normalized score scale has a minimal value of -100 and a maximum one of + 100. Whenever an alternative has a positive score, it entails more positive effects than negative, therefore leading towards sustainable development. The normalized score can be used to rank the alternatives (Rosén, o.a., 2013).

3.2.4 Uncertainty Analysis

The effects of the remedial alternatives are not possible to be assessed exactly, as there is uncertainty when scoring the environmental and social domains and when given quantifications to the economic domain. Uncertainty includes epistemic uncertainty (results from lack of knowledge) and aleatory uncertainty (natural variability). Uncertainty is also a consequence of human subjectivity when scoring the criteria.

SCORE treats the uncertainty by following a Monte Carlo simulation approach, where statistical distributions represent the uncertainties in both scores and quantitative metrics.

When scoring for **environmental and social domains**, beta distributions represent uncertainties. The distribution is assigned taking three steps: 1) for each sub-criterion within the environmental and social domain, selection of the possible range of scoring; 2) estimation of the most likely score within the range assigned previously; 3) assigning the uncertainty level of the assessment of the most likely effect as low, medium or high.

When monetizing cost and benefit items for **economic domain**, log-normal distributions are used to calculate uncertainties. The process includes two steps: 1) include the most likely value (MLV) of the present value (PV) of each benefit and cost items; 2) assigning the uncertainty level of the estimation of the MLV as low, medium or high, see Rosén (2014) in Vochko (2014). SCORE presents the probabilistic distribution with the credibility (or certainty) of the interval between LCL (lower credibility limit or lowest reasonable PV) and UCL (upper credibility limit or largest reasonable PV) equal to 90%. To additional information about uncertainty in the CBA, see Söderqvist (2014) in Brinkhoff (2014).

3.2.5 Current application

To enable the practical application of SCORE, a computer tool embedded in Excel was developed and has been used to assess the sustainability of several remediation projects case-studies (VOLCHKO, o.a., 2014).

Presently, SCORE is designed to assess alternatives of remedial actions with a fixed future land-use. As the tool is right now, it is not considered to be suitable to compare different future land-uses, to support decision-making in land-use planning processes, see Rosén (2014) in Vochko (2014).

As mentioned, the assessment of the economic domain is done by performing a CBA, whereas the environmental and the social domains have a semi-quantitative approach.

4 Case Study. Fixfabriken Site

This chapter provides information about the site chosen as a case-study, Fixfabriken in Göteborg, namely general information, present land uses, site conditions, as the local geology, hydrogeology, topography, archaeological relevance, contamination issues and additional site restrictions.

4.1 General information

The case study Fixfabriken site is located in Majorna, Gothenburg. There is an on-going process of developing a new detailed plan of that area, carried out by the Urban Planning Office (Stadsbyggnadskontoret) at the Municipality of Gothenburg. The future land uses are not yet defined in detail. Furthermore, Fixfabriken site is one of the case studies included in the Balance 4P project.

4.2 Short description of the area

The case study site has an area of approximately 10 ha and is located in the city of Gothenburg, in Majorna, not too far away from the city center. According to the land uses showed in Figure 4-1, the site is divided into four different parts: (1) the Fixfabriken industrial area, at the south /southwest boundary; (2) the Bus garage; (3) the Tram hall, at the east side; and (4) along the boulevard Karl Johansgatan, which corresponds to the north / northeast boundary, also mentioned in a simplified way as Road area. Figure 4-1 and Figure 4-2 give an idea of the present uses.

Figure 4-1 Existing land uses at Fixfabriken area. Reference Alternative (own illustration).

Figure 4-2 Photos from Fixfabriken site, including the 4 different parts of the site (Google Maps).

4.3 Local natural conditions

A summarized description on the local natural conditions includes the geology, hydrogeology and topography of the site and surroundings.

4.3.1 Geology

The site is located in an area with glacial and postglacial clay, which is normally on top of glacial till, that overlays bedrock. Local glaciofluvial deposit (sand and gravel) exists such as on the west and southwest of the site, which corresponds to the so called Sandarna area (SWECO, 2012). Figure 4-3 shows an extract of the Geological Map where the site is identified with a dashed black square.

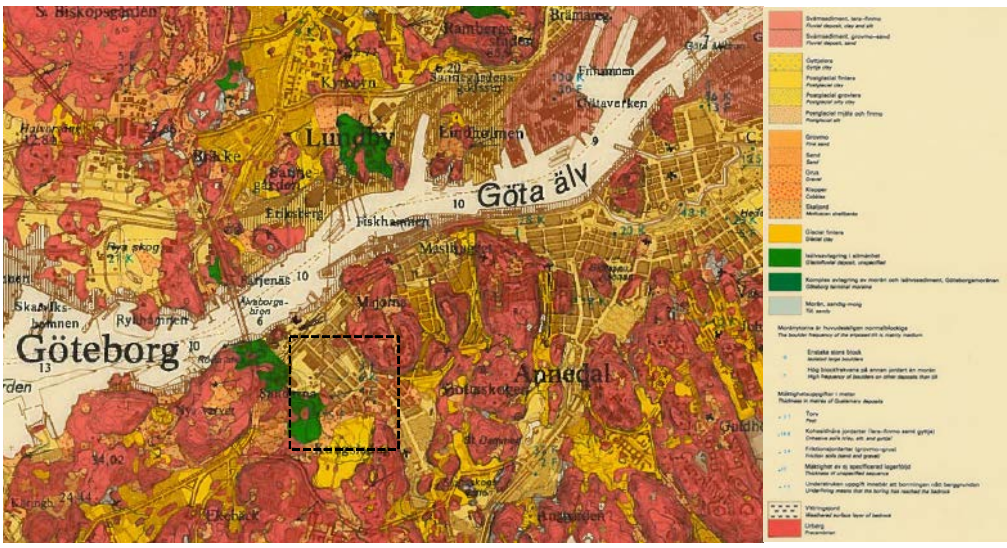


Figure 4-3 Geological map of the Gothenburg region (SGU, 1985).

It can be considered that a typical soil profile in the area has the following layers (Sweco, 2012):

- Asphalt
- Filling (sand, gravel and stones)
- Clay
- Till (in general), and sand and gravel (southern part of the site)
- Bedrock

Clay occurs around 20 m above sea level, and along the Göta älv river valley the clay layer has a thickness of about 10 to 15 m (Golder Associates, 2010).

4.3.2 Hydrogeology

Based on the topography, groundwater is expected to flow in direction to the river (Golder Associates, 2010).

The area is likely to have a first upper unconfined "aquifer" in the top layers above the clay, and a second confined aquifer between the clay and the bedrock. In the vicinity of the area, it doesn´t exist an aquifer of importance for water supply purposes (SWECO, 2012).

Based on field investigations from June 2010, the groundwater table is detected between 1.05 and 1.61 m below the surface level at the Bus garage area. Very wet clay is detected 3 – 3.5 m below the ground surface (Golder Associates, 2010).

4.3.3 Topography

The site is located in between a hill and a plain area, with the highest elevation on the west and south western sides, at the Fixfabriken factory part, and the lowest at the Tram hall and the northern part of the street Karl Johansgatan.

All the areas are relatively flat (terraced), with some height differences in between areas.

There is a difference of height of several meters between the adjacent road to Fixfabriken area and the ground level in the bus garage.

At present, there is a difference in height of about 1.5-2 m between the ground levels in the bus garage and the tram hall (Golder Associates, 2010).

4.4 Land uses and constraints

The description mainly focuses on the previous and present land uses and the known or expected contamination in the Fixfabriken area. An overview of the archaeological relevance of the area is also provided.

The information on soil conditions at the site was mainly provided by Christian Carlsson, specialist in soil contamination, from the Real Estate Office at the municipality of Gothenburg, and reports of environmental surveys in the area.

Mats Sandin, archaeologist from the County Administrative Board (Länsstyrelsen of Västra Götaland) provided most of the information on historical and archaeological background. Additional available information of the area is also considered.

A more detailed description of the different parts of the Fixfabriken area and an overview of the present conditions is provided below.

4.4.1 Fixfabriken factory

The Fixfabriken factory was built in the late 40s and no previous activity is known at the place. Since its construction, several activities that pose a risk of contamination have taken place (Carlsson, 2014).

At the Fixfabriken factory, several products have been manufactured over the years. At present, fittings for doors and windows are manufactured (SWECO, 2012). In the factory there are both workshop and surface treatment works (Carlsson, 2014). Over a fairly long period, since Fixfabriken started to operate and until the 1980s, large amounts of trichloroethylene, a chlorinated solvent, was used as a degreasing agent for washing of metal parts (SWECO, 2012a).

Fixfabriken is classified to risk class 1, i.e. the highest risk class, in the MIFO database administered by the County Administration. The high class is due to (1) the use of hazardous materials (between 4 and 5 ton of cyanide/year as well as several tons of trichloroethylene - approximately 3 tons are estimated to be released to the air yearly), (2) the complex geology that make the area vulnerable to spreading of contaminants, and (3) the sensitive uses in the nearby areas such as housing (Länsstyrelsen Västra Götalands Län, 2013). Trichloroethylene, or “TRI”, is a contaminant with high toxicity, which easily spreads far away from the contaminant source (Carlsson, 2014). It is a chlorinated hydrocarbon and a dense non-aqueous phase liquid (DNAPL), which typically makes the spreading difficult to predict and also often difficult to remediate.

During field investigations by soil and groundwater sampling on the site by SWECO in 2012, PAHs levels that exceed the Swedish guideline values were detected. Despite the fact that no chlorinated solvents were found in the first investigation, it was later identified in a second investigation by SWECO in 2013. The second investigation sampled pore gas, collected below the part of the building where chlorinated solvents were used most intensively. It was concluded that the contamination have spread mainly along and in the pipe network (SWECO, 2012a).

The soil and groundwater sampling and investigation of the soil layers, in 2012 was done in drilled boreholes outdoor. Contaminants analyzed include metals, oils (including aliphatic and aromatic carbons and poly-aromatic hydrocarbons - PAH), volatile compounds, polychlorinated biphenyl (PCB) or cyanide, depending on the sample analyzed (soil, water or asphalt). Five of the soil samples revealed PAH and aromatics contamination at levels higher than the Swedish generic guideline values for industrial areas (less sensitive uses - MKM), and in one of those samples the PAH concentration exceeded the guideline value for hazardous waste. Three additional samples do not fulfil the Swedish generic guideline values for sensitive uses for PAH. Lead was also found in one soil sample at levels exceeding the guideline values for less sensitive uses and chrome in one sample exceeding the guideline values for sensitive use (KM). No traces from the specific metal plating operation at the site were detected in this investigation. The overall conclusion was that no significant soil or groundwater contamination was found, although some samples from the loading area showed minor contamination. This is frequently encountered in industrial and urban areas, and it was concluded that the contamination resulted not from the specific industrial activity (Fixfabriken), but probably was caused by spilling from trucks or cars (SWECO, 2012).

A later investigation focused on analyses of gas samples in 8 boreholes. For each sample point both the content of chlorinated solvents in the pumped gas and partly the content of degradation products of this solvent are reported. The results show that there are traces of chlorinated solvents and that trichloroethylene is present in highest concentration. There is also a clear level of degradation product dichloroethene (SWECO, 2012a).

In this second investigation, 2 layers of concrete were detected, of about 15 cm each, although thicker in some parts (45 cm). In some parts, a layer of at least 20 cm of filling with a content of sand and stone was detected. In one of the points clay was found at about 55-60 cm from the basement concrete. The report states that it is likely that the remains of tri occur mainly in the filling materials that are below the concrete floor in the basement and above the underlying clay. Since leakage from sewer pipes appears to be the most likely propagation path, trenches are most likely contaminated (SWECO, 2012a).

4.4.2 Bus garage

The bus garage was constructed in the late 70s and includes several on-site activities that are likely to cause soil contamination. There are or have been e.g. garages, car washes, truck service, temporary boiler house. The bus garage is constructed on top of filling material with a thickness varying between 1 and 4 m. The filling material is likely to include waste in some parts, and poses a risk of contamination. In the south-eastern part the filling material is approximately 3 m thick (Carlsson, 2014).

In the south-eastern part of the bus garage, a leakage of diesel was detected in 2005. The leakage occurred in a pressurized transmission line between a fuel tank and the garage. From there, the diesel had spread to the soil and to the wastewater system. Subsequent remediation was done with pumping of a total of 11 m^3 of diesel out of the ground. Remediation of soil was conducted but only to a limited extent. Soil investigations concluded that approximately 1500 m^2 were polluted by the leakage. The investigations also detected pollution in the filling material not derived from the leakage. The filling material included waste bricks, scrap metal, wood and asphalt (Carlsson, 2014).

In 2010, an investigation was conducted at the bus garage site close to areas that pose greater risk of contamination, namely at areas of handling and storage of oil and diesel, at the northern and south-eastern parts. Contaminants analyzed were petroleum hydrocarbons in the form of aliphatic and aromatic hydrocarbons (including PAH - polycyclic aromatic hydrocarbons) in samples of soil and groundwater. Contamination was found in the soil and groundwater samples but at levels below the guideline values for the current land use (less sensitive use). Concrete samples were also collected and analyzed, all samples showing values below the limits of hazardous waste. The conducted investigation does not include the area that was previously remediated and which may have some residual contamination (Golder Associates, 2010). Despite of complying with the guideline values for less sensitive use, some contaminants have concentration levels above the ones allowed for a sensitive use, namely aliphatic (H - high molecular weight) in two of the soil sampling points, PAH (M - medium molecular weight) in one sample and PAH (H - high molecular weight) in two sampling points.

According to the samples collected when investigating the soil at the bus garage area, the filling material has a thickness between 0.5 m and 1.5 m. No waste was detected in the filling. Below the filling material there is clay, dry crust clay, silty gravelly clay or silty sandy clay (Golder Associates, 2010).

4.4.3 Tram hall

The existing tram hall was built in the 40s and entails risk of contamination due to the present and past activities e.g.: garages and workshops, boilers systems, laundry and electric transformers (Carlsson, 2014).

The southern part of the tram hall is confirmed contaminated due to a diesel leakage that took place at the neighboring bus garage area (Carlsson, 2014).

Additionally, it is expected that there is filling material in parts of the area with a thickness of 0.5-1 m, which might carry some contamination (Carlsson, 2014).

4.4.4 Karl Johansgatan boulevard area

Along the street Karl Johansgatan which forms the northeast boundaries of the area, and in the neighboring areas, several activities have been conducted that can pose risks of soil contamination: petrol stations, cleaning operations, workshops, warehouses, a former bus garage and traffic. Two petrol stations in operation (Shell and Preem) and a former petrol station (Hydro) along the Karl Johansgatan are the main concerns in terms of risk of soil contamination with hydrocarbons, but also metals (Carlsson, 2014).

Known contamination exists both in the Shell petrol station in operation since the 50s on the northern limit, and at the area of the former Hydro petrol station on the northern border of the residential area that operated between 30s until 2010. Remediation operations were conducted at the Hydro petrol station area although contamination remains in the soil down to several meters from the surface (Carlsson, 2014).

Some contamination (mainly hydrocarbons and metals) is likely to exist also at the Preem petrol station area, which is operating since the 60s (Carlsson, 2014).

Filling material is likely to be present, which typically is contaminated to a varying degree, depending on the origin of the filling material. The depth of the filling is probably of 1-2 m, although it can be thicker more locally (Carlsson, 2014).

4.4.5 Other areas

Around the Fixfabriken area, the Mölnlycke sewing thread factory has been operating. In the 90s, a leakage from an oil-fired boiler was detected. Despite remediation was carried out in the area there is still suspicion of remaining contamination. As so, Mölnlycke sewing thread factory is registered in Länsstyrelsen as area with risk class 3 (moderate risk) (Carlsson, 2014).

Other activities or properties not described here might also pose risk of soil contamination. Example is the content of the filling materials or the traffic areas (Carlsson, 2014).

4.4.6 Overview of the contamination in the case-study site

A summary of the contamination at the site is presented in Figure 4-4. The expected contamination is divided into: known contamination but uncertain boundaries; likely contamination; and unlikely contamination. The expected contaminants are chlorinated solvents, hydrocarbons (mainly fuels) and metals. The thickness of the filling material is also shown in the figure. As Figure 4-4 shows, a significant part of the area has soil with known contamination or soil that is likely to be contaminated.

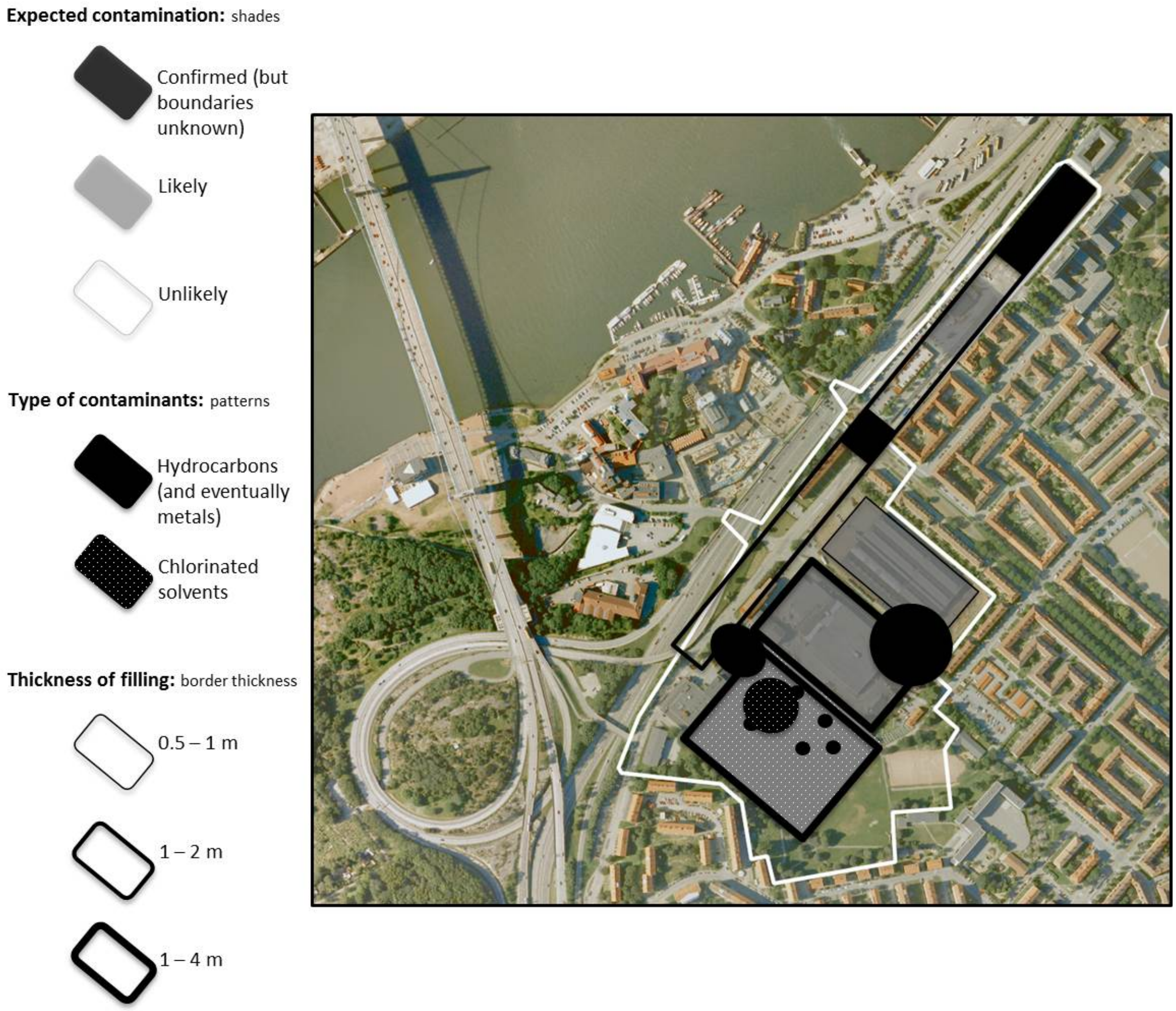


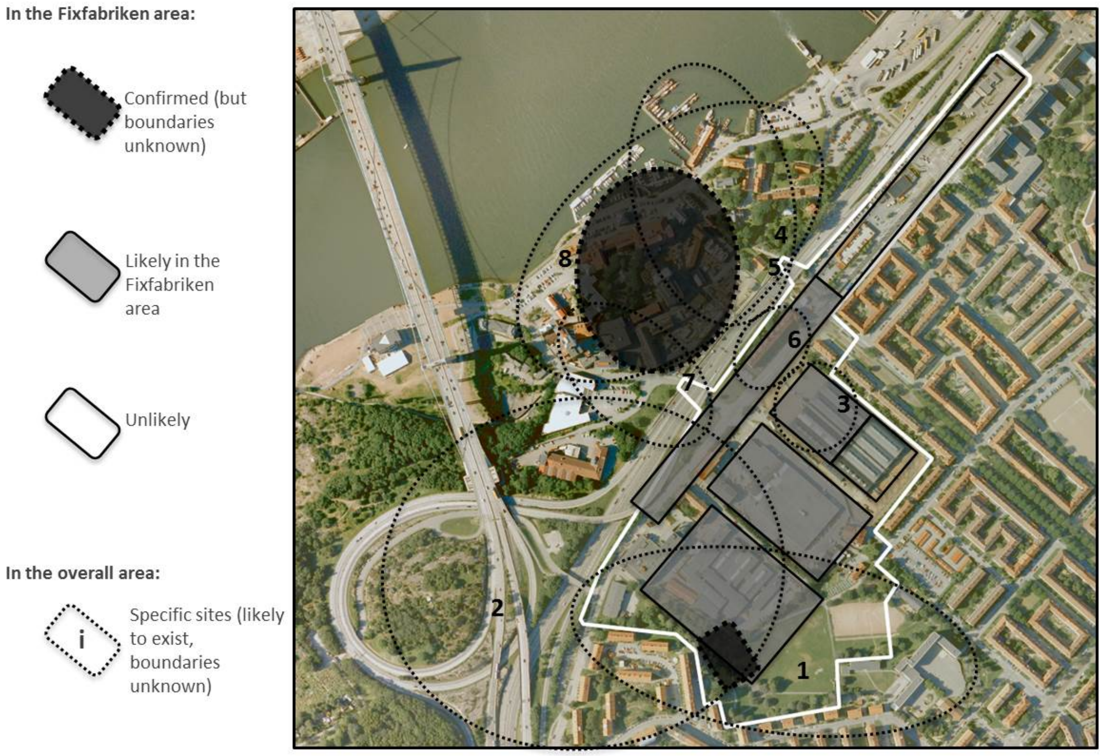
Figure 4-4 Overview of the soil contamination at the Fixfabriken area (own illustration).

4.4.7 Archaeology in the area and surroundings

People are known to exist in the Gothenburg area as early as 12000 years ago (so, 10000 B.C.). By the time of 6000 B.C., people lived in an area called Sandarna, just adjacent to the Fixfabriken industrial area. Archaeological excavations were done in 1912, 1930, 1942, and more recently in 2007, locating different tools and objects. Excavations showed that the area has been used for a long time, with settlements being overlaid from different times. The oldest settlement from 6000 years B.C. is from the Early Stone Age (n^o. 1 in Figure 4-5), and is covered by a layer of sand and gravel of about 3 m thick. On the top of this layer a more recent settlement was found, from the Late Stone Age, from around 3000 years B.C. (Göteborgs Stad. Park och natur). The geographical limits are unknown (Sandin, 2014).

Additionally, historical facts and different clues contained in documents and findings raise the suspicion of remains of other archaeological sites around or partially within the Fixfabriken area, namely from the fourteen to the eighteen century A.C.. Some of the possibilities are: military camp area from 1500s-1600s A.C. in the south / southern areas of Fixfabriken (2); old dam from 1500s-1600s A.C. in the north area of the tram terminal, including the boulevard (3); old harbour and activities related from 1500s-1 700s A.C. (4), the Swedish East India Trade Company from 1700s-1800s A.C. (5), brick production for the castle, from 1500s-1600s A.C. (6), and the city Älvsborgsstaden from the sixteen century A.C. (7), located in the area between the boulevard (or even including it) and the margins of the river Göta. There is also real evidence of Gamla Älvsborg (7), with a castle and fortress, from the 1300-1600s A.C., since excavations detected archaeological remains (Sandin, 2014).

An overview of the archaeological heritage is systematized in Figure 4-5. The areas are classified depending on the likelihood of archaeological remains to exist: known archaeological sites, although the physical boundaries are unsure; likeliness that archaeological remains exist; and low probability of remains to exist. The mentioned potential archaeological sites are also represented despite of the uncertainty regarding this information.



1 – Early stone age culture "Sandarna settlement" (6000 B.C.) and prehistoric settlements from neolithic age (late stone age); 2 - Military camp (1500s-1600s A.C.); 3 - Damm (1500s-1600s A.C.); 4 - Old harbour and related activities (1500s-1700s A.C.); 5 - Swedish East India Trade Company (1700s-1800s A.C.); 6- Possible brick production for the castle (1500-1600s A.C.); 7 - City Älvsborgsstaden (1500s A.C.); 8 - Gamla Älvsborg (1300-1600s A.C.).

Figure 4-5 Overview of the archaeology sites at the Fixfabriken area (own illustration adjusted by Sandin (2014)

As Figure 4-5 shows, a significant part of the area can be considered as likely to have archaeological remains. The already confirmed Stone Age Sandarna archaeological site includes at least the southern part of the Fixfabriken area, although the exact boundaries of the site are unknown.

5 Alternatives of urban regeneration. Fixfabriken Site Case-Study

This chapter presents the process of identifying, discarding and selecting alternatives of urban redevelopment of the site for further assessment. A description of the alternatives to assess is provided, which includes both the intended future land uses and the remedial process to allow safe use of the site and the surroundings. The reference alternative or expected situation in the future if no specific action is taken is also suggested.

5.1 Reference Alternative

The reference alternative corresponds to the present situation (Figure 4-1), keeping a relatively underused area within an attractive part of Göteborg. The Fixfabriken area mainly includes industrial land use and transport infrastructure. It can be divided into four different parts: (1) the Fixfabriken factory; (2) the bus garage; (3) the tram hall; and (4) the road Karl Johansgatan.

Fixfabriken factory has industrial activities since the 40s. The companies HSB Göteborg and Balder now own Fixfabriken factory. The soils at Fixfabriken factory are contaminated to some extent by trichloroethylene, a chlorinated solvent. The present spreading conditions of the contaminants are unknown. Archaeological remains are known in the area, although its boundaries are not defined.

The **Bus garage** property is owned by the municipality.

The **Tram hall** is operated by Göteborgs Spårvägar, which has a permit to be operating in the coming years. The municipality owns the property. Recently the company showed to the municipality its interest to keep operating the tram hall further after this deadline.

The **Karl Johansgatan area** includes the area that stands in between the road Karl Johansgatan, which is the main road serving the local neighbourhood, and the highway E45. It also includes the road Karl Johansgatan itself. Road infrastructures and traffic generate adverse effects, namely noise, air pollution and visual intrusion. Land use at the area includes two petrol stations, a residential area, parking lots, crossings and small green areas in between.

5.2 Process for selection of alternatives

The process is initiated by defining remediation and urban redevelopment as the scope of the alternatives and by pinpointing the relevant criteria to then identify possibilities of alternatives for the case-study site. As shown in Figure 5-1, preliminary choices of alternatives takes into account the local conditions and development restrictions, as well as preferences of stakeholders and possibilities of differentiated land uses and remedial approaches. Future land uses include new residential areas, new and existing industrial / office areas, and the tram hall, either at the present location or relocated. The identified possibilities are either rejected either selected to the following steps. Feed-back from the stakeholders contributes to define the set of alternatives.

A Cost-Benefit Analysis initiates its assessment. When the quantitative assessment of the economic domain results in no sustainable economic alternatives, the process is reinitiated. Otherwise, a qualitative assessment of the environmental and social domains is performed and integrated together with the CBA results in a MCA. When no sustainable alternatives are found, the process restarts. This iterative process comes to an end when the alternatives are assessed as sustainable, thereby allowing support to decision-making process. Although not evident in the diagram, both the alternatives ranking and the uncertainty of the result provide relevant assistance in the proposal.

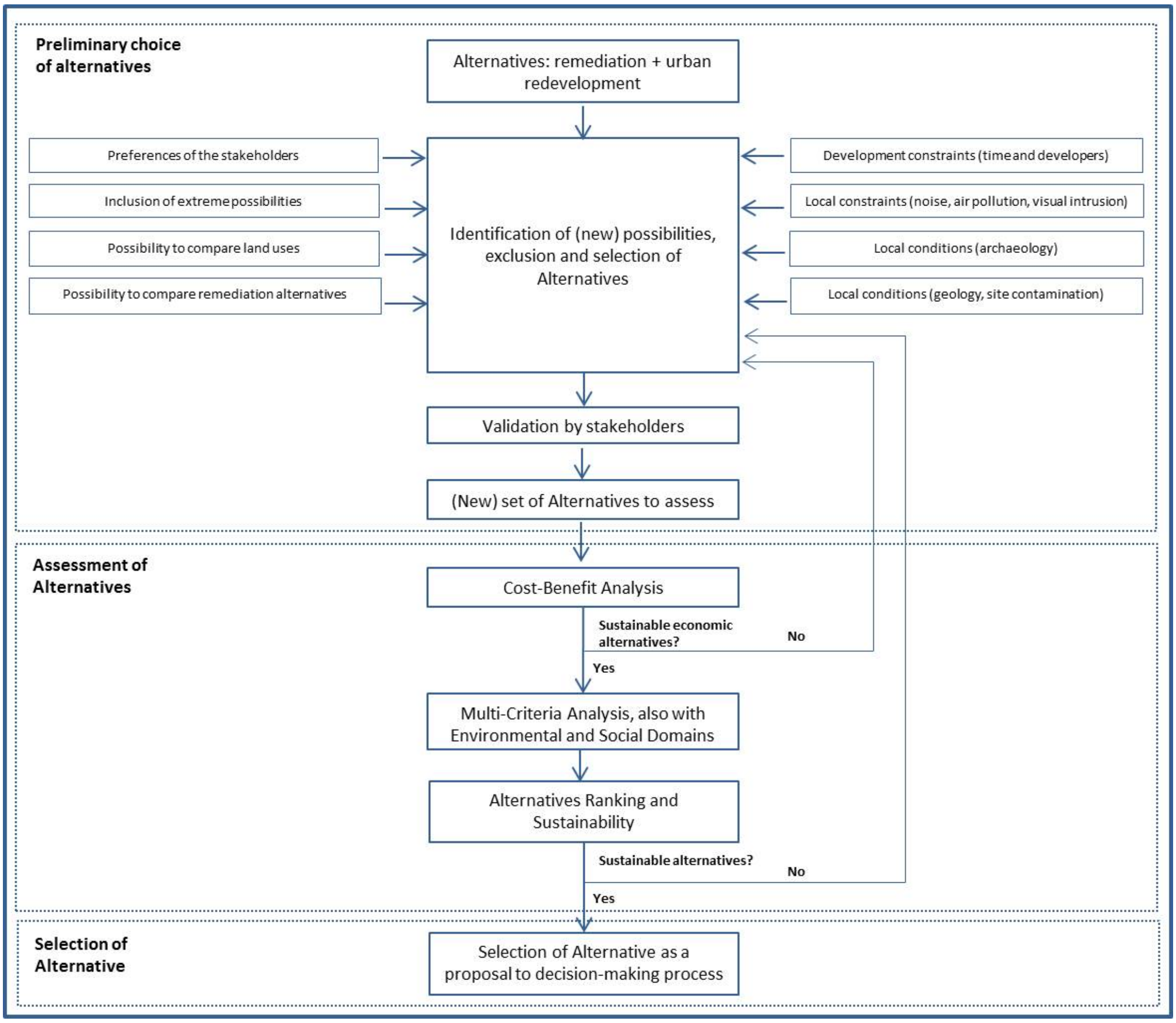


Figure 5-1 Approach for selection of alternatives (own illustration).

5.3 Alternatives to assess

Based on the methodology presented, sets of alternatives with a maximum of five different alternatives of future land use and remediation are identified and selected for assessment.

Along the process, several alternatives and set of alternatives were considered. Here are shown alternatives in two of the sets considered, namely set 1 and set 2.

5.3.1 Set 1 of alternatives to assess

The first set of five alternatives includes alternatives A1 (1), A2 (2), B1 (3), B2 (4) and C (5), which are shown in Figure 5-2. Those were defined by the author and the supervisor, based on the methodology of Figure 5-1.

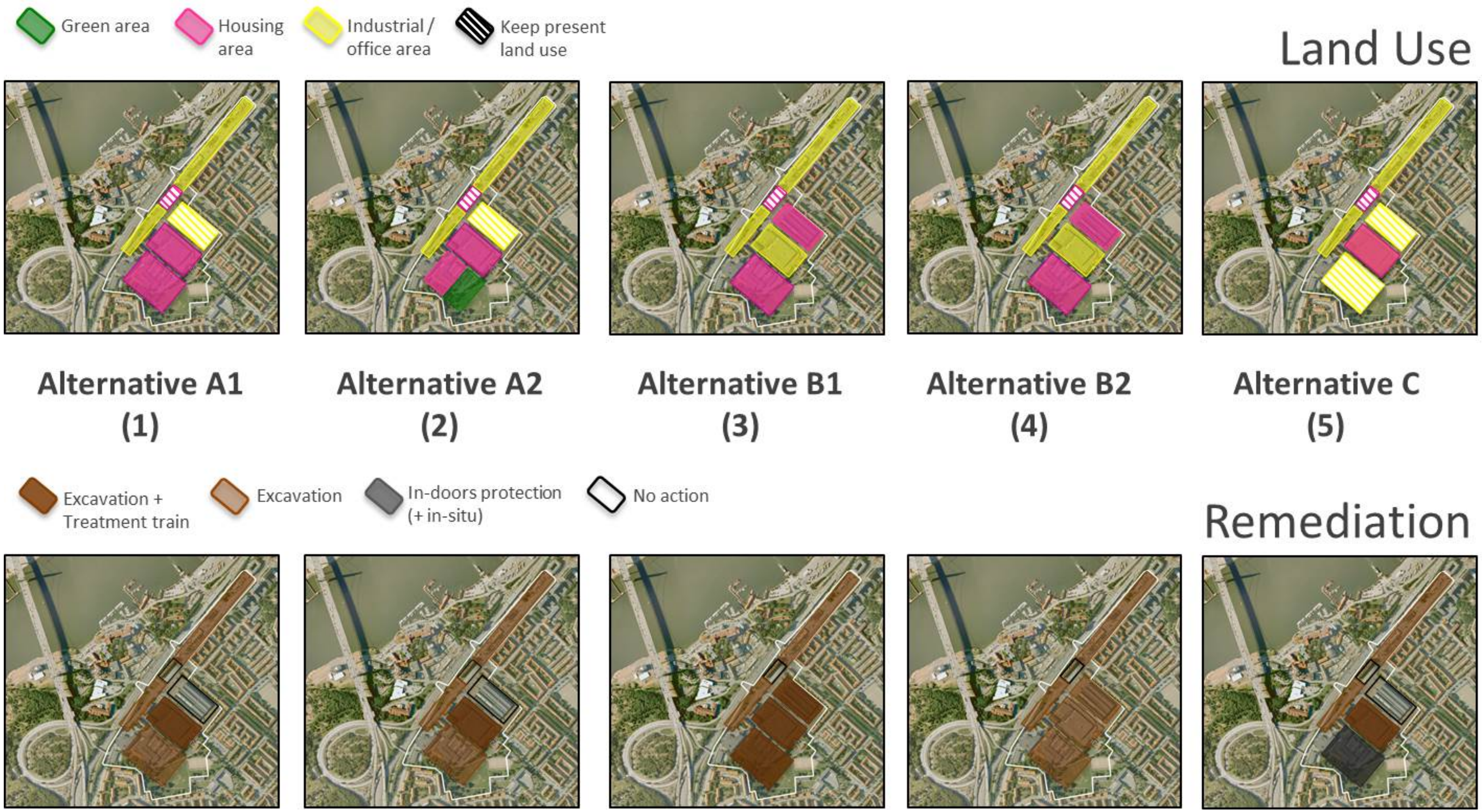


Figure 5-2 Overview of the five alternatives of land use and remediation at Fixfabriken, in set 1 of alternatives (own illustration).

The notation for the Alternatives A1, A2, B1, B2 and C reflects a stronger similarity of some alternatives, with smaller variations, which can be on the land use side (Alternatives A1 and A2, B1 and B2) or on the remediation process side (Alternatives A1 and A2), thus allowing the evaluation of a specific option of land use or remediation technology.

The degree of change of the land use varies from one alternative to another. Alternative C keeps existing land uses as much as possible, preserving existing buildings, whereas in Alternatives B1 and B2 all the parts include new land uses and new construction.

The remediation strategy is adjusted depending on the type of future land use and on the options made regarding keeping buildings (some parts of the site in Alternatives A1, A2 and C) or constructing new buildings (some parts of the site in all Alternatives). In the majority of the situations with no change of the existent industrial land use and existing buildings, a no remediation action is considered to those specific places (specific parts at all the Alternatives). When preserving existent buildings in industrial areas with contaminants in the subsurface environment (Fixfabriken factory), the option of protecting the working environment is considered (Alternative C). Furthermore, remedial options include more conventional approaches such as excavation of soil and materials that need then to be transported and taken care of off-site, as well as more complex remediation processes, “treatment trains”, which aim to handle the contaminated soil on-site. In this initial set of alternatives, in-situ remediation is not proposed as it is normally more time consuming, and more uncertainties about the results are expected, which are undesired aspects for new urban developments. Instead, speed and an end result, which is relatively easy to verify is attractive for constructions companies.

5.3.1.1 Alternative A1 (1) of set 1

Alternative A1 only differs from Alternative A2 at the southern part of Fixfabriken factory.

Fixfabriken factory is demolished. The existent filling material beneath the buildings and the superficial part of the underneath layer are dug out. New buildings for residential use with some commercial areas in the ground floors are then constructed, starting 5 years from now. Redevelopment occurs during 2 years. The excavated contaminated materials are not further treated but are transported off-site to final disposal, possibly with some treatment at the disposal site.

The **Bus garage** is demolished and the existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. New buildings for residential use, with commerce/offices/services at the ground floor, are then constructed, starting 8 years from now. It is assumed that the development occurs in two stages. The total redevelopment period is 3 years. The mentioned digging of the soils is the first step of a treatment train to remediate this area on-site, consisting of digging, sieving and soil washing applied to the smaller fractions of the soil. At least part of the soil dug is suitable to be reused on-site, thus reducing the volume that needs to be transported off-site to final disposal.

The **Tram hall** is kept as it is. No remediation action is taken, unless any extreme hot-spots are found in the coming investigations.

The existing petrol stations at the **street Karl Johansgatan** are demolished, and the present residential area is kept. New buildings for industrial and office use are then constructed, starting 10 years from now. It is assumed that the redevelopment occurs in several stages, during 8 years. No action is taken in the remaining area along the street Karl Johansgatan. Regarding remediation action, the filling materials beneath the places to be reconstructed are dug out. The excavated contaminated materials are not adequate to be used on-site and are transported off-site to final disposal, possibly with some treatment at the disposal site.

5.3.1.2 Alternative A2 (2) of set 1

Alternative A2 only differs from Alternative A1 at the southern part of Fixfabriken factory.

Fixfabriken factory is demolished. The existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. New buildings for residential use are then constructed in the northern part, starting 5 years from now, and during 2 years. The southern part becomes a green area. The excavated contaminated materials are not adequate to be used on-site and are transported off-site to final disposal, possibly with some treatment at the disposal site. It is worth to mention that the southern area of Fixfabriken factory is probably dug to a lower depth as no buildings are then constructed there. This allows a lower disturbance of the underneath layers, thus lower probability of affecting the known archaeological remains from the Early stone age culture ”Sandarna settlement” (6000 B.C.) and prehistoric settlements from Neolithic age (late stone age), and eventual remains of an ancient military camp (1500s-1600s A.C.).

The **Bus garage** is developed in the same way as described in Alternative A1.

The **Tram hall** is treated as described in Alternative A1.

The **Karl Johansgatan area** is handled in the same way as described in Alternative A1.

5.3.1.3 Alternative B1 (3) of set 1

Alternative B1 only differs from Alternative B2 on the type of remediation actions considered.

The future land uses in **Fixfabriken factory** are developed in the same way as described in Alternative A1. On the contrary, the remediation strategy is quite different. Whereas Alternative A1 only includes excavation, Alternative B1 considers the digging followed by a treatment train to remediate this area on-site as much as possible, consisting of sieving and soil washing applied to the smaller fractions of the soil. At least part of the soil dug is suitable to be reused on-site, thus reducing the volume that needs to be transported off-site to final disposal.

The **Bus garage** is demolished and the existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. A new tram hall is constructed, starting 8 years from now, and during 2 years. The excavated soil is handled in the same way as described in Alternative A1. Different future land uses is thus the main difference between Alternative A1 and B1.

The **Tram hall** is demolished and the existent filling materials beneath and eventually the superficial part of the underneath layer is dug of. New buildings for residential use, with commerce/offices/services at the ground floor, are then constructed, starting 10 years from now. It is assumed that the redevelopment occurs in 2 different stages, in a total of 3 years. The mentioned digging of the soils is the first step of a treatment train to remediate this area on-site, consisting of digging, sieving and soil washing applied to the smaller fractions of the soil. At least part of the soil dug is suitable to be reused on-site, thus reducing the volume that needs to be transported off-site to final disposal.

The **Karl Johansgatan area** is developed in the same way as described in Alternative A1.

5.3.1.4 Alternative B2 (4) of set 1

Alternative B2 only differs from Alternative B1 on the type of remediation actions considered.

Fixfabriken factory is handled in the same way as described in Alternative A1. As mentioned before, B2 only differs from Alternative B1 on the type of remediation actions considered, as the treatment train is missing here. Therefore, the excavated contaminated materials are not adequate to be used on-site and are transported off-site to final disposal, possibly with some treatment at the disposal site.

The **Bus garage** is developed in the same way as in Alternative B1, except what concerns remediation action, as the treatment train is missing in Alternative B2. Consequently, the excavated materials are sent to final disposal, eventually with some treatment at the disposal site, instead of being used on-site.

The **Tram hall** is developed as described in Alternative B1, despite the treatment train to perform a most complete remediation on-site is not considered. Thus, the excavated contaminated materials in Alternative B2 are not adequate to be used on-site and are transported off-site to final disposal, possibly with some treatment at the disposal site.

The **Karl Johansgatan area** is handled in the same way as described in Alternative A1.

5.3.1.5 Alternative C (5) of set 1

Alternative C keeps the existing constructions at the area to a highest extent, namely Fixfabriken and the tram hall.

Buildings and uses (industrial and offices) at **Fixfabriken factory** are kept as they are. Buildings are renovated to assure an adequate indoor air quality, namely through active ventilation. Depending on further investigation of the soil contamination in the area, in-situ remediation might be carried out if there are any hot-spots / left source areas. This is assumed to occur 2 years from now.

The **Bus garage** is developed in the same way as described in Alternative A1.

The **Tram hall** is treated as described in Alternative A1.

The **Karl Johansgatan area** is handled in the same way as described in Alternative A1.

5.3.1.6 Time plan to set 1 of alternatives

For each one of the 4 areas within the site, a timeframe of the actions that are part of the urban regeneration of Fixfabriken site is estimated, which is based on information provided by the stakeholders. The timeframe for each alterative of set 1 is presented in Table 5-1.

Table 5-1 – Timeframe for the remediation (R), construction (C) and / or adjustments (A) in each of the 4 different parts in the Fixfabriken site, to each Alternative in Set 1 (own illustration)

ALTERNATIVES AND AREAS	YEARS																		
Alternative 1 (A1)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**…**
Fixfabriken factory					R	C													
Bus garage								R	C/R	C									
Tram hall																			
Road Karl Johansgatan										R	C	R	C	R	C	R	C		
Alternative 2 (A2)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**…**
Fixfabriken factory					R	C													
Bus garage								R	C/R	C									
Tram hall																			
Road Karl Johansgatan										R	C	R	C	R	C	R	C		
Alternative 3 (B1)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**…**
Fixfabriken factory					R	C													
Bus garage								R	C										
Tram hall										R	C/R	C							
Road Karl Johansgatan										R	C	R	C	R	C	R	C		
Alternative 4 (B2)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**…**
Fixfabriken factory					R	C													
Bus garage								R	C										
Tram hall										R	C/R	C							
Road Karl Johansgatan										R	C	R	C	R	C	R	C		
Alternative 5 (C)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**…**
Fixfabriken factory		A																	
Bus garage								R	C/R	C									
Tram hall																			
Road Karl Johansgatan										R	C	R	C	R	C	R	C		

In the time plan, “R” stands for remedial action taking place, “C” means that the construction works of the future land uses are proceeding, and “R/C” is applied to the areas developed in more than one stage, with remediation and construction taking place simultaneously but in different parts of a specific area. “A” stands for adjustments regarding measures to avoid human exposure to contaminants.

5.3.2 Set 2 of alternatives to assess

The second set of five alternatives includes alternatives A1 (1), A2 (2), A3 (3), B (4) and C (5), which are shown in Figure 5-3. Those were defined by the author and by the research team of the Balance 4P project, and not submitted again to the stakeholders.

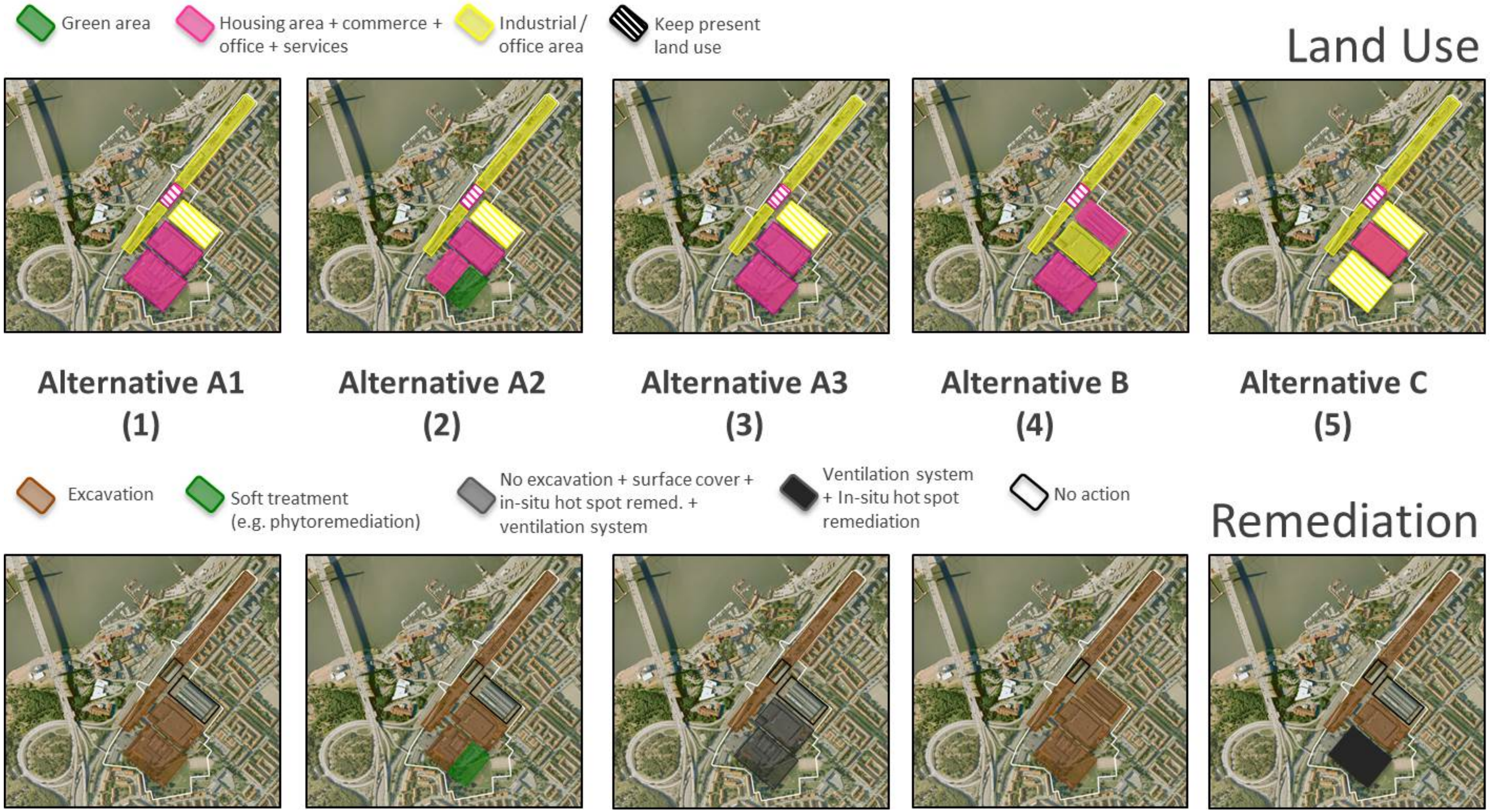


Figure 5-3 Overview of the five alternatives of land use and remediation at Fixfabriken, in set 2 of alternatives (own illustration).

The notation for the Alternatives A1, A2, A3, B and C reflects a stronger similarity of some alternatives, with smaller variations, which can be on the land use side (Alternatives A1, A2 and A3, specially A1 and A3). Similarities on the remediation process (Alternatives A1 and B) are not taken into account in the notation. The combinations allow evaluation of specific options of land use or remediation technology.

The degree of change of the land use varies from one alternative to another. Alternative C keeps existing land uses as much as possible, preserving existing buildings, whereas in Alternatives A3 all the parts include new land uses and new construction.

The remediation strategy is adjusted depending on the future land uses and on the options made regarding keeping buildings as they are (some parts of the site in Alternatives A1, A2, A3 and C), keeping the existent foundations even if demolishing the buildings (some parts of the site in Alternatives A3 and C) or constructing new buildings from the scratch (some parts of the site in all the Alternatives, but especially in A1, A2 and B). In the majority of the situations with no change of the existent industrial land use and existing buildings, a no remediation action is considered to those specific places. The remediation strategies include dig and dump approach (at least one part of the site in all alternatives, but specially in alternatives A1, A2 and B), soft remediation in a small green area within the site (A2), ventilation and hot-spot in-situ remediation (parts of the site in A3 and C), and additional surface covering of not excavated surfaces that are having future housing land use (parts of the site in A3).

5.3.2.1 Alternative A1 (1) of set 2

Fixfabriken factory is demolished. The existent filling material beneath the buildings and the superficial part of the underneath layer are dug out. New buildings for residential use with some commercial areas in the ground floors are then constructed, starting 5 years from now. Redevelopment occurs during 2 years. Housing heights 4-7 floors, with a mix of rental and condominium apartments. The excavated contaminated materials are not further treated but are transported off-site to final disposal, possibly with some treatment at the disposal site.

The **Bus garage** is demolished and the existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. New buildings for residential use, with commerce/offices/services at the ground floor, are then constructed, starting 8 years from now. It is assumed that the development occurs in two stages. The total redevelopment period is 3 years. Housing heights 4-7 floors, with a mix of rental and condominium apartments. The excavated contaminated materials are not further treated but are transported off-site to final disposal, possibly with some treatment at the disposal site.

The **Tram hall** is kept as it is. No remediation action is taken, unless any extreme hot-spots are found in the coming investigations.

The existing petrol stations at the **street Karl Johansgatan** are demolished, and the present residential area is kept. New buildings for industrial and office use are then constructed, starting 10 years from now. It is assumed that the redevelopment occurs in several stages, during 8 years. No action is taken in the remaining area along the street Karl Johansgatan. Regarding remediation action, the filling materials beneath the places to be reconstructed are dug out. The excavated contaminated materials are not adequate to be used on-site and are transported off-site to final disposal, possibly with some treatment at the disposal site.

5.3.2.2 Alternative A2 (2) of set 2

Fixfabriken factory is demolished. In the northern part the existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. New buildings for residential use are then constructed in the northern part, starting 5 years from now, and during 2 years. Housing heights 4-7 floors, with a mix of rental and condominium apartments. The excavated contaminated materials are not adequate to be used on-site and are transported off-site to final disposal, possibly with some treatment at the disposal site. The southern part becomes a green area to preserve and emphasize the historical importance of the site. The upper soil layers are remediated through soft techniques (e.g. phytoremediation), i.e. no excavation unless any extreme hot-spots are found in the coming investigations. This allows a lower disturbance of the underneath layers, thus lower probability of affecting the known archaeological remains from the Early stone age culture ”Sandarna settlement” (6000 B.C.) and prehistoric settlements from Neolithic age (late stone age), and eventual remains of an ancient military camp (1500s-1600s A.C.).

The **Bus garage** is developed in the same way as described in Alternative 1. The **Tram hall** is treated as described in Alternative 1. The **Karl Johansgatan area** is handled in the same way as described in Alternative 1.

5.3.2.3 Alternative A3 (3) of set 2

The future land uses in this alternative are developed quite differently from alternatives 1 & 2 and also the remediation strategy is different. Whereas Alternatives 1 & 2 emphasize excavation, this alternative focuses on no excavation, but instead using surface cover, hot-spot in-situ remediation and active ventilation of new constructions to prevent vapors in-door to manage contamination.

Consequently, when the **Fixfabriken factory** is demolished, foundations and sub-surface structures are left untouched to disturb the sub-soil as little as possible. These structures are instead ventilated to manage contamination. Around buildings, in-situ and soft techniques (e.g. phytoremediation) are potentially applied in combination with surface cover. New buildings are constructed on top of existing sub-soil structures. Ground floor is ventilated to manage contamination and used as commercial space. 2 floors of apartments are built on top of these for residential use, with a mix of rental and condominium apartments. In addition, 20% of the apartments are subsidized for low-income families. Development starts approximately 5 years from now, and is carried out during 2 years.

The **Bus garage** is demolished without digging out the existent filling materials beneath the buildings. New buildings are constructed on top of the surface with piling where needed, to disturb the sub-soil as little as possible. New buildings are constructed on top of existing sub-soil structures. Ground floor is ventilated to manage contamination and used as commercial space. 3-4 floors of apartments are built on top of these for residential use, with a mix of rental and condominium apartments. In addition, 20% of the apartments are subsidized for low-income families. Around buildings, in-situ and soft techniques (e.g. phytoremediation) are potentially applied in combination with surface cover. Development starts 4 years from now, and is carried out during 2 years.

The **Tram hall** is kept as it is. No remediation action is taken, unless any extreme hot-spots are found in the coming investigations.

The **Karl Johansgatan area** is developed in the same way as described in Alternative 1.

5.3.2.4 Alternative B (4) of set 2

Fixfabriken factory is handled in the same way as described in Alternative 1.

The **Bus garage** is demolished and the existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. A new tram hall is constructed, starting 8 years from now, and during 2 years. The excavated soil is handled in the same way as described in Alternative 1. Different future land uses is thus the main difference between Alternative 1 and 4.

The **Tram hall** is demolished and the existent filling materials beneath and eventually the superficial part of the underneath layer is dug out. New buildings for residential use (a mix of rental and condominium apartments), with commerce/offices/services at the ground floor, are then constructed, starting 10 years from now. It is assumed that the redevelopment occurs in 2 different stages, in a total of 3 years. The excavated contaminated materials are not adequate to be used on-site and are transported off-site to final disposal, possibly with some treatment at the disposal site.

The **Karl Johansgatan area** is handled in the same way as described in Alternative A1.

5.3.2.5 Alternative C (5) of set 2

This alternative keeps the existing constructions at the area to a highest extent, namely Fixfabriken and the tram hall.

Buildings and uses (industrial and offices) at **Fixfabriken factory** are kept as they are. Buildings are renovated to assure an adequate indoor air quality, namely through active ventilation. The space is used as incubator for new businesses and social entrepreneurs. Depending on further investigation of the soil contamination in the area, in-situ remediation might be carried out if there are any hot-spots / left source areas. This is assumed to occur 2 years from now.

The **Bus garage** is developed in the same way as described in Alternative 1, but with housing heights of 7-15 floors, with a mix of rental and condominium apartments. In addition, 20% of the apartments are subsidized for low-income families.

The **Tram hall** is treated as described in Alternative 1. The **Karl Johansgatan area** is handled in the same way as described in Alternative 1.

5.3.2.6 Time plan to set 2 of alternatives

For each one of the 4 areas within the site, a timeframe of the actions that are part of the urban regeneration of Fixfabriken site is estimated, which is based on information provided by the stakeholders. The timeframe for each alterative of set 2 is presented in Table 5-2.

Table 5-2 – Timeframe for the remediation (R), construction (C) and / or adjustments (A) in each of the 4 different parts in the Fixfabriken site, to each Alternative in Set 2 (own illustration)

ALTERNATIVES	YEARS																		
Alternative 1 (A1)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**…**
Fixfabriken factory					R	C													
Bus garage								R	C/R	C									
Tram hall																			
Road Karl Johansgatan										R	C	R	C	R	C	R	C		
Alternative 2 (A2)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**…**
Fixfabriken factory					R	C													
Bus garage								R	C/R	C									
Tram hall																			
Road Karl Johansgatan										R	C	R	C	R	C	R	C		
Alternative 3 (A3)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**…**
Fixfabriken factory					R	C													
Bus garage								R	C										
Tram hall										R	C/R	C							
Road Karl Johansgatan										R	C	R	C	R	C	R	C		
Alternative 4 (B)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**…**
Fixfabriken factory					R	C													
Bus garage								R	C										
Tram hall										R	C/R	C							
Road Karl Johansgatan										R	C	R	C	R	C	R	C		
Alternative 5 (C)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**…**
Fixfabriken factory		A																	
Bus garage								R	C/R	C									
Tram hall																			
Road Karl Johansgatan										R	C	R	C	R	C	R	C		

5.3.3 Alternatives not considered

The alternatives presented previously are just part of the many possible options of future land use and remediation strategies at the Fixfabriken area. Below are mentioned other possibilities as well as the reason why they are discarded and not subject to further analysis. The excluded possibilities are highlighted bellow with bold.

5.3.3.1 Alternatives of future land uses not considered

Alternatives not confined exclusively to the Fixfabriken area are not considered at all in both alternatives sets 1 and 2, as the goal is to focus on the mentioned area to which a detailed plan is going to be developed in the short term.

The urban redevelopment of the Fixfabriken site aims to combine different land uses, namely housing, commercial, offices and services areas as well as industrial areas. As so, alternatives with **very low diversity of land uses** are excluded.

One of the particularities of the area is the historical background and archaeological remains that can be an opportunity or a threat to the process of developing this urban area. Although in some areas of the site sub-surface is left nearly untouched thereby avoiding disturbance of the known and potential remains (A2 in both sets and A3 and C in set 2), the alternatives chosen end up to **don't explore that much the consequences of having archaeological remains**. Therefore, the alternatives are not detailed to the point of considering eventual integration in the redevelopment, removal and/or relocation of remains, neither adjustment of the construction works. The option of **no construction in larger areas** is discarded, as it is probably non economically feasible from an urban redevelopment point of view.

Industrial land use at the Fixfabriken factory is interesting from some perspectives, in particular due to lower demands of soil contamination levels with this type of land use. On the other hand, monetary compensation from the sale of industrial / office areas is expected to be much less attractive compared with the sale of residential areas. The option for future **industrial use based on the construction of new buildings at Fixfabriken** is soon discarded, as it can be considered that is not realistic neither interesting for the owner of the property.

It was initially considered to **relocate the Tram hall out of the Fixfabriken site**. Further developments advised to discard this possibility, as the company that manages the tram hall showed to the municipality its interest to keep operating the tram hall as it is, eventually with some renovation. New possibilities emerged, such as keeping it exactly as it is (Alternatives A1, A2 and C in both sets, and A3 in set 2) or relocating it to the neighboring bus garage area (Alternative B1 and B2). The alternative of keeping the **tram hall in the same location but underground** is excluded as there are some technical / operation limitations. The **temporary relocation to the bus garage area** to allow the renovation / construction of a new tram hall in the present location, is also not included as part of one alternative to be assessed.

Housing is not included as an alternative within the **street Karl Johansgatan area**. The nearby road infrastructures and traffic affect this area adversely, causing noise, air pollution, visual intrusion and even some constrains in the mobility of people, which is not a desired situation for a residential area. **No changes on the present residential area located at the street Karl Johansgatan area** are considered.

Not only the mentioned space and land use perspectives, but also the time dimension has been taken into account in the process of defining, selecting and excluding alternatives. As mentioned when describing each one of the five alternatives, the future interventions are very likely to have different timings depending on each of the four parts in the Fixfabriken area, starting by the Fixfabriken factory and ending at the Karl Johansgatan area. On the other hand, the whole area is in use. While in the process of defining alternatives, **new temporary uses prior to the long-term future land uses are excluded**, as it is not clear when the on-going activities will be phased out / cease, or, as in the case of Fixfabriken factory, the intervention is expected to start as soon as possible in the coming years, thus not been reasonable to consider temporary uses.

Some other possibilities were identified, although not mentioned here.

5.3.3.2 Alternatives of remediation not considered

At first, the aim with the remediation was to apply **in-situ remediation** as much as possible. Soon it was realized that this might not realistic in the Fixfabriken area, due both to the sub-surface conditions and to the high interest of the stakeholders in using the areas on short-medium term. Geology and soil contamination are complex in the area and available data is limited. Thus there are significant uncertainties about the present conditions. The risk of using less conventional remediation solutions or less tested ones is high, and has the potential to increase the cost and time necessary to achieve contamination levels that are compatible with the Swedish guideline values. Instead, speed and an end result, which is relatively easy to verify, is attractive for constructions companies. New temporary uses prior to the long-term future land uses are excluded, thus preventing testing in-situ remediation strategies, namely gentle remediation options, that otherwise could occur after the on-going activities cease and before the future interventions are implemented. By the time of defining alternatives to set 1, it was considered that when having more detailed data about the soil conditions, in-situ methods should be re-evaluated, especially due to the contamination by chlorinated solvents. Later on, when obtaining unfavorable results from the economic assessment of set 1, in-situ remediation possibilities were no longer excluded when selecting alternatives to set 2.

Gentle remediation options, that are one possible in-situ remediation strategy, are discarded even for the south area in the Alternative A2 in set 1 that becomes a green area, as at the time it was assumed that when demolishing buildings and digging the underneath filling materials, most of the contamination is removed, thus excluding phytoremediation as a remediation alternative needed, despite of the future green area land use.

At first, **monitoring of natural attenuation** is considered as an interesting possibility as a gentle remediation option, to areas that are not going to be intervened in the short term, and that have some contamination but not require a remediation action in the actual conditions, namely due to its less sensitive land use. This is the case of the street Karl Johansgatan area. Despite the benefits of knowing how the contamination changes over time, the costs during the process might be significant for a small-size enterprise, especially considering that at the end the action previous to the construction works will probably be the same with or without this follow-up. As so, this option is not included neither in alternatives of set 1 and 2.

Nevertheless, it might be interesting to include **in-situ actions for site specific conditions**, as described very shortly in Alternative C in set 1, and more intensively in alternatives A3 and C in set 2. It can also be applied in other situations, as long as further investigations of soil and groundwater contamination reveal hot spots of former or on-going contamination sources.

From a large range of possibilities of remediation, only a few are considered as alternatives to be assessed, as five alternatives per set is the maximum number assumed to be feasible to assess, and also different land uses have to be included.

At same point it is also considered that several remediation strategies are not possible in some areas as known or expected **archaeological remains** can be affected by digging operations and changes in the soil conditions (higher exposure to oxygen, increase in the biological activity, among others, could degrade organic material in some of the remains). However, no remediation technology is discarded exclusively based on these concerns.

Since an early stage of the process it is assumed that the remediation process is theoretically more demanding in areas with **future residential use** than with **future industrial / office use**. In fact, the Swedish guideline values for the levels of pollutants in the soil are higher for industrial use compared with more sensitive land uses as residential use. Once again, due to the site-specific conditions, it is later on realized that the amount of soil and materials to dig doesn´t vary so much with the future use, and the remediation approach is so quite similar.

The four different parts in the Fixfabriken area have different owners and diverse deadlines, both regarding when each place is available for intervention and when construction works have to start, thus restricting possible **integrated and common solutions of remediation for the overall area**. Otherwise, it could potentially lead to beneficial scale economies / synergies.

6 Application of SCORE at the Fixfabriken Site

This chapter presents the sustainability assessment of the selected alternatives to the Fixfabriken site case-study, considering the economic, social and environmental domains, by using SCORE tool. Both results of the Cost-Benefit Analysis performed for alternatives set 1 and set 2, and a complete assessment within the MCA to set 2 of alternatives are presented.

6.1 Economic domain (CBA)

In the economic domain, the timeframe is considered in the Net Present Value SCORE calculations of a benefit or cost item in each specific area of the case-study site. When proceeding with the calculations, it is necessary to define which fraction of benefit or cost has immediate effects and which needs to be discounted. As a rule, depending on the beginning and on the ceasing of the action, the year when the benefit or the cost starts and the number of years during which the cost or benefit last are defined. However, in some specific situations, the start of a certain action of the regeneration process is the beginning of a non-ending period of costs or benefits. That is the case, for example, when monetizing benefits of improving non-acute health conditions. Furthermore, how the economic benefits or costs occur during the years also depends on the timeframe settled. The most common situation is to have constant benefits each year, despite for some situations no constant cost or benefits are expected. That is the case of the road Karl Johansgatan to all the alternatives assessed, where the remediation and redevelopment occur in more than one stage, and consequently large variations along the years occur.

The discount rate considered in the calculations in SCORE is left unchanged (3.5%).

As four different areas within the same site compose each alternative, calculations for each cost and benefit item are done separately for each area. The final Net Present Value (NPV) is the sum of the NPV of each part of the site.

The several major steps are further on presented.

6.1.1 Identification and preliminary assessment of costs and benefits

At an early stage, to each alternative of regeneration of Fixfabriken site, cost and benefit items included in the matrix of the economic domain in SCORE are considered and classified regarding its likelihood of type of importance. Table 6-1 and Table 6-2 show the classification of the relevance of each cost and benefit item to each alternative, respectively of set 1 and set 2. Items of importance are marked with “X”, items of somewhat importance are marked with “(X)”, and the ones not relevant, marked with “0”.

Table 6-1 – Relevance of each cost and benefit items in the Fixfabriken site, to each Alternative in set 1 (own illustration)

Benefit Items	Sub items	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
B1. Increased property values	B1. Increased property value on site	X	X	X	X	(X)
B2. Improved health	B2a. Reduced acute health risks	0	0	0	0	0
	B2b. Reduced non-acute health risks	X	X	X	X	X
	B2c. Other types of improved health	(X)	(X)	(X)	(X)	(X)
B3. Increased provision of ecosystem services	B3a. On site	0	(X)	0	0	0
	B3b. In the surroundings	(X)	(X)	(X)	(X)	0
	B3c. Others	0	0	0	0	0
B4. Other than B2 and B3	B4. Other positive externalities	0	0	0	0	0

Cost Items	Sub items	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
C1. Remediation costs	C1a. Costs for investigations and design	X	X	X	(X)	X
	C1b. Costs for contracting	X	X	X	X	(X)
	C1c. Capital costs due to allocation of funds	(X)	(X)	X	(X)	(X)
	C1d. Costs for the remedial action	X	X	X	X	X
	C1e. Costs for monitoring programs	X	X	X	X	(X)
	C1f. Project risks	X	X	X	X	(X)
C2. Impaired health due to the remedial action	C2a. On site	0	0	0	0	0
	C2b. Due to transports	X	X	(X)	X	(X)
	C2c. At disposal sites	X	X	(X)	X	(X)
	C2d. Other due to remediation	(X)	(X)	(X)	(X)	(X)
C3. Decreased provision of ecosystem services on site	C3a. On site	0	0	0	0	0
	C3b. Outside the site	(X)	(X)	(X)	(X)	(X)
	C3c. At the disposal site	(X)	(X)	0	X	(X)
C4. Other costs than C2 and C3	C4. Other negative externalities	(X)	0	(X)	(X)	0

Table 6-2 – Relevance of each cost and benefit items in the Fixfabriken site, to each Alternative in set 2 (own illustration)

Benefit Items	Sub items	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
B1. Increased property values	B1. Increased property value on site	X	X	X	X	X
B2. Improved health	B2a. Reduced acute health risks	0	0	0	0	0
	B2b. Reduced non-acute health risks	X	X	X	X	X
	B2c. Other types of improved health	(X)	(X)	(X)	(X)	(X)
B3. Increased provision of ecosystem services	B3a. On site	(X)	(X)	(X)	(X)	(X)
	B3b. In the surroundings	(X)	(X)	(X)	(X)	(X)
	B3c. Others	(X)	(X)	(X)	(X)	(X)
B4. Other than B2 and B3	B4. Other positive externalities	(X)	(X)	(X)	(X)	(X)

Cost Items	Sub items	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
C1. Remediation costs	C1a. Costs for investigations and design	X	X	X	X	X
	C1b. Costs for contracting	(X)	(X)	(X)	(X)	(X)
	C1c. Capital costs due to allocation of funds	(X)	(X)	(X)	(X)	(X)
	C1d. Costs for the remedial action	X	X	X	X	X
	C1e. Costs for monitoring programs	X	X	X	X	X
	C1f. Project risks	X	X	X	X	X
C2. Impaired health due to the remedial action	C2a. On site	(X)	(X)	(X)	(X)	(X)
	C2b. Due to transports	(X)	(X)	(X)	(X)	(X)
	C2c. At disposal sites	(X)	(X)	(X)	(X)	(X)
	C2d. Other due to remediation	(X)	(X)	(X)	(X)	(X)
C3. Decreased provision of ecosystem services on site	C3a. On site	0	0	0	0	0
	C3b. Outside the site	(X)	(X)	(X)	(X)	(X)
	C3c. At the disposal site	X	X	(X)	X	(X)
C4. Other costs than C2 and C3	C4. Other negative externalities	X	(X)	(X)	X	(X)

6.1.2 Assessment of costs and benefits

An attempt was made to monetize the very important items as much as possible. Other items classified as somewhat important are also considered, whenever its calculation is possible. Each benefit and cost is detailed further on, with the specific methods, calculations and results presented in the correspondent the Appendix.

6.1.2.1 Benefit B1. Increased property values

"Benefit B1. Increased property values" includes one sub-item, named "**B1. Increased property value on site**". It corresponds to the increase in land value of the site once a remedial action has been performed (Chalmers University of Technology, 2014). In Fixfabriken case-study, the evaluation takes also into account the allowed / expected future land use to each alternative.

Despite of the high uncertainty, this sub-item can be monetized. A specific methodology is considered, based on the Hexion case-study and on additional assumptions, as described on the Appendix. The calculated net present value is shown.

6.1.2.2 Benefit B2. Improved health

"Benefit B2. Improved health" includes sub-items "B2a. Reduced acute health risks", "B2b. Reduced non-acute health risks" and "B2c. Other types of improved health, e.g. reduced anxiety".

"**B2a. Reduced acute health risks**" sub-item is a benefit of the remedial action (Chalmers University of Technology, 2014). In this case-study it is not monetized, as the Swedish EPA (Naturvårdsverket) methodology for the calculation of the acute health risks focus on contaminants that are not expected to exist in the Fixfabriken site, as explained by Jenny Norrman (July 2014). Therefore, this item is considered as no important.

The "**B2b. Reduced non-acute health risks**" sub-item is a benefit of the remedial action, that is monetized in Fixfabriken case-study by applying a specific methodology, which is partially based on the approach used in the Hexion case-study (Landström & Östlund, 2011). The method, assumptions and calculations performed are presented in the Appendix. The calculated net present value is also shown.

"**B2c. Other types of improved health, e.g. reduced anxiety**" sub-item includes other types of improved health than reduced acute (B2a) and non-acute health risks (B2b), such as reducing psychosocial conditions that might create anxiety among visitors and neighbors (Chalmers University of Technology, 2014). Only a qualitative evaluation is suggested for this case-study. This sub-item is judged to be somewhat important.

6.1.2.3 Benefit B3. Increased provision of ecosystem services

"Benefit B3. Increased provision of ecosystem services" includes sub-items "B3a. Increased recreational opportunities on site", "B3b. Increased recreational opportunities in the surroundings" and "B3c. Increased provision of other ecosystem services".

"**B3a. Increased recreational opportunities on site**" sub-item is related to the creation of increased recreational opportunities on the site (Chalmers University of Technology, 2014). In this case-study, only a qualitative evaluation is presented. This sub-item is recognized as having a somewhat importance, as it can be assumed that small green areas along the site and a sport facility will be created.

"**B3b. Increased recreational opportunities in the surroundings**" sub-item is related to the creation of increased recreational opportunities in the surroundings of the site (Chalmers University of Technology, 2014). In this case-study, a qualitative evaluation is considered. Apart from Alternative 5 in both set 1 and 2, in which the redevelopment of the site is limited to some extent (only Bus garage and Road area are intervened), this sub-item is recognized as having a somewhat importance in all the Alternatives, as a more appealing site will probably lead to a greater use of the neighboring existent green area.

“**B3c. Increased provision of other ecosystem services**” sub-item is related to positive effects on other ecosystem services than recreational opportunities (B3a and B3b) (Chalmers University of Technology, 2014). Due to the expected future land use, no other ecosystem services are predicted as relevant. This sub-item is considered as being of “somewhat important” if considering that the new construction will include small green areas.

6.1.2.4 Benefit B4. Other positive externalities than B2 and B3

“Benefit B4. Other positive externalities than B2 and B3” includes one sub-item, named “**Benefit B4. Other positive externalities**”. It corresponds to other positive externalities than improved health (B2) and increased provision of ecosystem services (B3) (Chalmers University of Technology, 2014). Even though some alternatives are less invasive in the Fixfabriken factory area, which is expected to have the most archaeological importance, it is too soon to include it as part of benefit B4. As so, all the alternatives are evaluated as of importance “0”.

6.1.2.5 Cost C1. Remediation costs

Cost “C1. Remediation costs” includes sub-items “C1a. Costs for investigations and design of remedial actions”, “C1b. Costs for contracting”, “C1c. Capital costs due to allocation of funds to the remedial action”, “C1d. Costs for the remedial action, including possible transport and disposal of contaminated soil minus possible revenues of reuse of contaminants and/or soil”, “C1e. Costs for design and implementation of monitoring programs including sampling, analysis and data processing” and “C1f. Project risks”.

Sub-item “**C1a. Costs for investigations and design of remedial actions**” corresponds to costs with site investigations and design of remedial actions, including institutional controls, and are specific to the remedial design (Chalmers University of Technology, 2014). On the other hand, sub-item “**C1b. Costs for contracting**” include costs associated with project management, technical support, and working environment, which are not specific to the remedial design (Chalmers University of Technology, 2014). Both this sub-items are considered as being included in further calculations in the sub-item C1d and C1e.

Sub-item “**C1c. Capital costs due to allocation of funds to the remedial action**” includes the interest paid for loans funding remedial action and depreciation of equipment/machines used for remedial action (Chalmers University of Technology, 2014). In the Fixfabriken case-study, the evaluation takes also into account the future land use defined to each alternative. This sub-item is monetized considering the values obtained for the Hexion case-study and additional assumptions, as described in the Appendix. The calculated net present value is also shown.

Sub-item “**C1d. Costs for the remedial action, including possible transport and disposal of contaminated soil minus possible revenues of reuse of contaminants and/or soil**” includes mobilization, remediation and demobilization work costs (Chalmers University of Technology, 2014). These costs are calculated in Fixfabriken case-study, despite this is not done to all the type of costs. A specific methodology partially based on the approach used in the Hexion case-study (Landström & Östlund,

2011) is applied. The method, assumptions and calculations performed are presented in the Appendix. The calculated net present value is also shown.

Sub-item "**C1e. Costs for design and implementation of monitoring programs including sampling, analysis and data processing**" is monetized considering the values obtained for the Hexion case-study and additional assumptions, as described on the Appendix. The calculated net present value is also shown.

Sub-item "**C1f. Project risks**" includes different risk cost categories (Brinkhoff, 2014). No monetization is done. In this case-study it is considered of being of importance.

6.1.2.6 Cost C2. Impaired health due to the remedial action

Cost "C2. Impaired health due to the remedial action" includes sub-items "C2a. Increased health risks due to the remedial action on site", "C2b. Increased health risks due to transports to and from the remediation site, e.g. transports of contaminated soil", "C2c. Increased health risks at disposal sites" and "C2d. Other types of impaired health due to the remedial action, e.g. increased anxiety".

Sub-item "**C2a. Increased health risks due to the remedial action on site**" corresponds to costs of increased health risks due to remedial action on site (Chalmers University of Technology, 2014). In the Fixfabriken case-study it is assumed that there are no risks to the workers during the remedial action, as it is known that the soil is contaminated and so proper health and safety procedures will be in place, which probably include the use by the workers of individual protection equipment to prevent the occurrence of contamination through the possible exposure pathways. For this reason, the sub-item is monetized with 0.

Sub-item "**C2b. C2b. Increased health risks due to transports to and from the remediation site, e.g. transports of contaminated soil**" is related to increased health risks because of transports to and from the site, namely due to accidents when transporting contaminated soil and when transporting refilling material (Chalmers University of Technology, 2014). It is monetized considering a method used for the Hexion case-study and additional assumptions, as described on the Appendix. The calculated net present value is also shown.

Sub-item "**C2c. Increased health risks at disposal sites**" includes costs due to consequences of the remedial action (Chalmers University of Technology, 2014). No monetization is performed, but instead, a qualitative appreciation is done. For most of the Alternatives, this sub-item is considered to be important, whereas to Alternative 3 and 5 it has a lower importance due to the lowest transport off-site of contaminated soil.

Sub-item "**C2d. Other types of impaired health due to the remedial action, e.g. increased anxiety**" includes, among other possibilities, the cost of causing psychosocial conditions that create anxiety among visitors and neighbors (Chalmers University of Technology, 2014). A classification of a somewhat important cost is assumed.

6.1.2.7 Cost C3. Decreased provision of ecosystem services on site

Cost "C3. Decreased provision of ecosystem services on site" includes sub-items "C3a. Decreased provision of ecosystem services on site due to remedial action, e.g. reduced recreational opportunities", "C3b. Decreased provision of ecosystem services outside the site due to the remedial action, e.g. environmental effects due to transports of contaminated soil" and "C3c. Decreased provision of ecosystem services due to environmental effects at the disposal site".

Sub-item "**C3a. Decreased provision of ecosystem services on site due to remedial action, e.g. reduced recreational opportunities**" is related to the effect of the remedial action in decreasing ecosystem services on site, such as reducing recreational opportunities on site while the remedial action is taking place (Chalmers University of Technology, 2014). It is assumed to be of no relevance.

On the other hand, sub-item "**C3b. Decreased provision of ecosystem services outside the site due to the remedial action, e.g. environmental effects due to transports of contaminated soil**" is the cost associated with the decrease of ecosystem services outside the site (except those at the disposal site, that is considered in C3c) (Chalmers University of Technology, 2014). The sub-item is classified as important or as somewhat important.

Regarding the sub-item "**C3c. Decreased provision of ecosystem services due to environmental effects at the disposal site**", it is considered that depending on the extent of soil expected to be received by a disposal site, the sub-item is classified as important or as somewhat important.

6.1.2.8 Cost C4. Other negative externalities than C2 and C3

Cost "C4. Other negative externalities than C2 and C3" includes sub-item "**C4. Other negative externalities**". This item considers other negative externalities than impaired health (C2) and decreased provision of ecosystem services (C3), that remediation can cause. The most common example is the reduction of cultural values through impairment or destruction of cultural heritage (Chalmers University of Technology, 2014). In the Fixfabriken case-study it is assumed that excavation necessary to remediation and further construction are potential threats to archaeological remains on-site. For this reason, this cost is classified as somewhat important, except to Alternatives 2 and 5 in both sets, and alternative 3 in set 2, where is considered as not being relevant.

6.1.3 Results of the CBA

The results are shown considering all specific methods and assumptions previously presented.

6.1.3.1 CBA for set 1 of alternatives

The Net Present Value calculated to each benefit and cost item to each alternative, as well as the total economic values are included in Table 6-3. The level of importance of the non-monetized items is stated. Depending on the item, uncertainties are classified as high or medium. The stakeholders or parts benefiting from it or supporting the costs are also mentioned.

Table 6-3 – Results of the CBA, in MSEK, and level of importance of the non-monetized items, to each Alternative in set 1 (based on Chalmers University of Technology (2014))

Main items	Sub-items	Alternative 1			Alternative 2			Alternative 3			Alternative 4			Alternative 5		
		P/B	Mode (MSEK)	Unc	P/B	Mode (MSEK)	Unc	P/B	Mode (MSEK)	Unc	P/B	Mode (MSEK)	Unc	P/B	Mode (MSEK)	Unc
B1. Increased property values	B1. Increased property value on site	DEV	112,1	H	DEV	84,45	H	DEV	111,3	H	DEV	111,3	H	DEV	57,11	H
B2. Improved health	B2a. Reduced acute health risks	EMP	(X)	M	EMP	(X)	M	EMP	(X)	M	EMP	(X)	M	EMP	(X)	M
	B2b. Reduced non-acute health risks	EMP	0,35	M	EMP	0,35	M	EMP	0,35	M	EMP	0,35	M	EMP	0,38	M
	B2c. Other types	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M
B3. Increased provision of ecosystem services	B3a. On site	No P/B	0,00	M	PUB	(X)	M	No P/B	0,00	M	No P/B	0,00	M	No P/B	0,00	M
	B3b. Off site	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	0,00	M
	B3c. Others	No P/B	0,00	M	PUB	(X)	M	No P/B	0,00	M	No P/B	0,00	M	No P/B	0,00	M
B4. Other positive externalities	B4. Other positive externalities	No P/B	0,00	M	No P/B	0,00	M	No P/B	0,00	M	No P/B	0,00	M	No P/B	0,00	M
C1. Remediation costs	C1a. Costs for investigations and design	No P/B		M	No P/B		M	No P/B		M	No P/B		M	No P/B		M
	C1b. Costs for contracting	No P/B		M	No P/B		M	No P/B		M	No P/B		M	No P/B		M
	C1c. Capital costs due to allocation of funds	DEV	2,23	M	DEV	2,23	M	DEV	2,94	M	DEV	2,94	M	DEV	1,39	M
	C1d. Costs for the remedial action	DEV	127,6	H	DEV	127,6	H	DEV	171,1	H	DEV	155,8	H	DEV	75,7	H
	C1e. Costs of monitoring programs	DEV	14,88	M	DEV	14,88	M	DEV	26,19	M	DEV	14,70	M	DEV	11,60	M
	C1f. Project risks	DEV	X	M	DEV	X	M	DEV	X	M	DEV	X	M	DEV	X	M
C2. Impaired health due to the remedial action (increased health risks)	C2a. On site	EMP	0,00	M	EMP	0,00	M	EMP	0,00	M	EMP	0,00	M	EMP	0,00	M
	C2b. Due to transports	EMP	2,56	M	EMP	2,56	M	EMP	3,05	M	EMP	3,42	M	EMP	1,47	M
	C2c. At disposal sites	EMP	X	M	EMP	X	M	EMP	(X)	M	EMP	X	M	EMP	(X)	M
	C2d. Other types	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M
C3. Decreased provision of ecosystem services due to remedial action	C3a. On site	PUB	0,00	M	PUB	0,00	M	PUB	0,00	M	PUB	0,00	M	PUB	0,00	M
	C3b.Off site	PUB	6,40	M	PUB	6,40	M	PUB	8,63	M	PUB	8,63	M	PUB	3,75	M
	C3c. At the disposal site	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	X	M	PUB	(X)	M
C4. Other negative externalities than C2 and C3	C4. Other negative externalities	PUB	(X)	M	PUB	0,00	M	PUB	(X)	M	PUB	(X)	M	PUB	0,00	M
NPV		**-41,24**			**-68,90**			**-100,20**			**-73,86**			**-36,45**		

The items affecting the most the results are B1 and C1d, to all the alternatives.

As can be seen, the total NPV is negative to all the alternatives, with the lowest value with Alternative 3 (- 100.2) and the highest values with Alternative 5 (- 36.45), closely followed by Alternative 1 (- 41.24).

6.1.3.2 CBA for set 2 of alternatives

The Net Present Value calculated to each benefit and cost item to each alternative, as well as the total economic values are included in Table 6-4. Depending on the item, uncertainties are stated as high or medium. The stakeholders or parts benefiting or supporting the costs are also mentioned in the table.

Table 6-4 – Results of the CBA, in MSEK, and level of importance of the non-monetized items, to each Alternative in set 2 (based on Chalmers University of Technology (2014))

Main items	Sub-items	Alternative 1			Alternative 2			Alternative 3			Alternative 4			Alternative 5		
		P/B	Mode (MSEK)	Unc	P/B	Mode (MSEK)	Unc	P/B	Mode (MSEK)	Unc	P/B	Mode (MSEK)	Unc	P/B	Mode (MSEK)	Unc
B1. Increased property values	B1. Increased property value on site	DEV	112,1	M	DEV	84,45	H	DEV	112,1	H	DEV	111,3	M	DEV	57,11	H
B2. Improved health	B2a. Reduced acute health risks	PUB		M	PUB		M	PUB		M	PUB		M	PUB		M
	B2b. Reduced non-acute health risks	PUB	0,35	M	PUB	0,35	M	PUB	0,35	M	PUB	0,35	M	PUB	0,38	M
	B2c. Other types	PUB	0,21	M	PUB	0,21	M	PUB	0,21	M	PUB	0,27	M	PUB	0,21	M
B3. Increased provision of ecosystem services	B3a. On site	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M
	B3b. Off site	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M
	B3c. Others	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M
B4. Other positive externalities	B4. Other positive externalities	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M
C1. Remediation costs	C1a. Costs for investigations and design	DEV	0,00	M	DEV	0,00	M	DEV	0,00	M	DEV	0,00	M	DEV	0,00	M
	C1b. Costs for contracting	DEV	0,00	M	DEV	0,00	M	DEV	0,00	M	DEV	0,00	M	DEV	0,00	M
	C1c. Capital costs due to allocation of funds	DEV	2,24	M	DEV	2,24	M	DEV	2,24	M	DEV	2,94	M	DEV	2,33	M
	C1d. Costs for the remedial action	DEV	65,93	L	DEV	58,17	M	DEV	43,08	H	DEV	84,27	L	DEV	47,07	M
	C1e. Costs of monitoring programs	DEV	13,43	M	DEV	13,43	H	DEV	13,43	H	DEV	14,70	M	DEV	9,68	H
	C1f. Project risks	DEV	X	M	DEV	X	M	DEV	X	M	DEV	X	M	DEV	X	M
C2. Impaired health due to the remedial action (increased health risks)	C2a. On site	EMP	0,00	M	EMP	0,00	M	EMP	0,00	M	EMP	0,00	M	EMP	0,00	M
	C2b. Due to transports	PUB	1,33	M	PUB	1,16	M	PUB	0,33	M	PUB	1,69	M	PUB	0,80	M
	C2c. At disposal sites	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M
	C2d. Other types	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M	PUB	(X)	M
C3. Decreased provision of ecosystem services due to remedial action	C3a. On site	PUB	0,00	M	PUB	0,00	M	PUB	0,00	M	PUB	0,00	M	PUB	0,00	M
	C3b.Off site	PUB	1,76	M	PUB	1,43	M	PUB	0,51	M	PUB	2,31	M	PUB	1,09	M
	C3c. At the disposal site	PUB	X	M	PUB	X	M	PUB	(X)	M	PUB	X	M	PUB	(X)	M
C4. Other negative externalities than C2 and C3	C4. Other negative externalities	PUB	X	M	PUB	(X)	M	PUB	(X)	M	PUB	X	M	PUB	(X)	M
NPV		**27,98**			**8,58**			**53,08**			**6,03**			**-3,27**		

As can be seen, the total NPV is positive to nearly all the alternatives, with alternative 3 having the highest NPV. The exception is Alternative 5, with a negative value of - 3.27.

6.2 Environmental and social domains

A qualitative assessment of the environmental and social domains in Fixfabriken site case-study is done in close collaboration with researchers from Chalmers University of Technology, who are part of the Balance 4P project. This assessment is focus on the set 2 of alternatives, as alternatives in set 1 demonstrated a deficient performance in the CBA and therefore were excluded in an earlier stage.

The weighting and scoring of the criteria in the environmental and social domains, as well as the motivation of the scoring chosen is shown in the Appendix.

6.3 Sustainability assessment by SCORE

The three domains are assumed as having the same importance, thus they are weighted equally.

The weighting of the benefit and cost items is achieved through the monetization of the items. The weighting of the environmental and social key-criteria was already shown in the Appendix.

The NPV to each item and each alternative (CBA in economic domain) and the scorings of the criteria (environmental and social domains) performed by / in SCORE, considering the level of uncertainty defined, are used in the calculations in SCORE. Thus, through Monte Carlo simulation using 10000 trials, the environmental and social sustainability scores, the economic sustainability (NPV, in MSEK) and/or the normalized total sustainability score are obtained.

6.3.1 SCORE analysis for set 1 of alternatives

Due to the unfavorable results obtained in the CBA for the economic domain, no weighting neither scoring of the criteria in the environmental and social domain is done. Nevertheless, a calculation of the Economic Sustainability is simulated. Figure 6-1 shows the economic sustainability where the different levels of uncertainties are taken into account in the calculations.

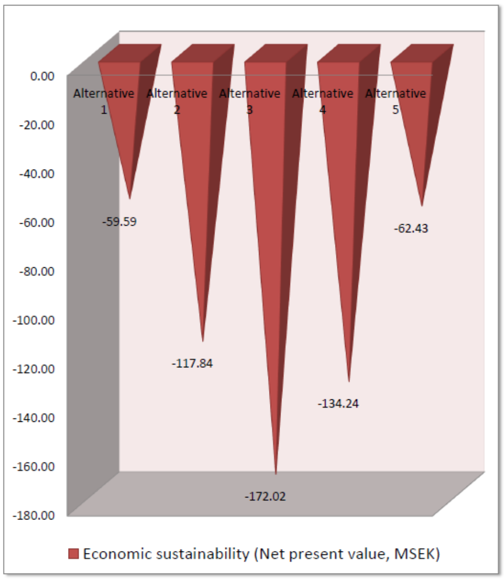


Figure 6-1 Sustainability Score: Economic sustainability for set 1 of alternatives (obtained from Chalmers University of Technology (2014)).

According to Figure 6-1, the net present value that measures the economic sustainability of alternatives in set 1 varies between – 172.02 millions of Swedish crowns (alternative 3) and – 59.59 millions of Swedish crowns (alternative 1, with values very close to the ones of alternative 5).

Continuing to look at the Economic effects of Alternatives in Set 1, a Distributional Analysis of the Present Cost Values and the Present Benefit Values is shown, respectively on the left side and on the right side of Figure 6-2.

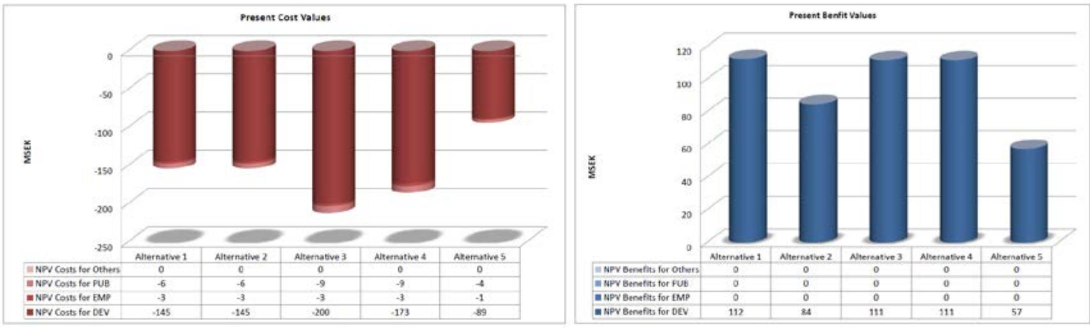


Figure 6-2 Distribution of the NPV costs and NPV benefits among the different stakeholders. Set 1 of alternatives (obtained from Chalmers University of Technology (2014)).

The costs are mainly focused on the developers although public and employers also are affected. On the other hand, developers are the ones most benefiting from the redevelopment of the site. Other parts that benefit include employers and public, although with values lower than 1 Million Swedish crowns and therefore not readable in Figure 6-2.

Once again, due to the very negative results, alternatives of set 1 are discarded.

6.3.2 SCORE analysis for set 2 of alternatives

By performing the monetization of the economic items (see 6.1.3.2), and by weighting and scoring the criteria in the environmental and social domain (see 6.2), additional calculations are performed in SCORE, using 10000 trials in the simulations. Figure 6-3 shows the sustainability scores for environmental and social domains, the NPV for the economic domain, as well as the normalized total sustainability score which integrates the three domains.

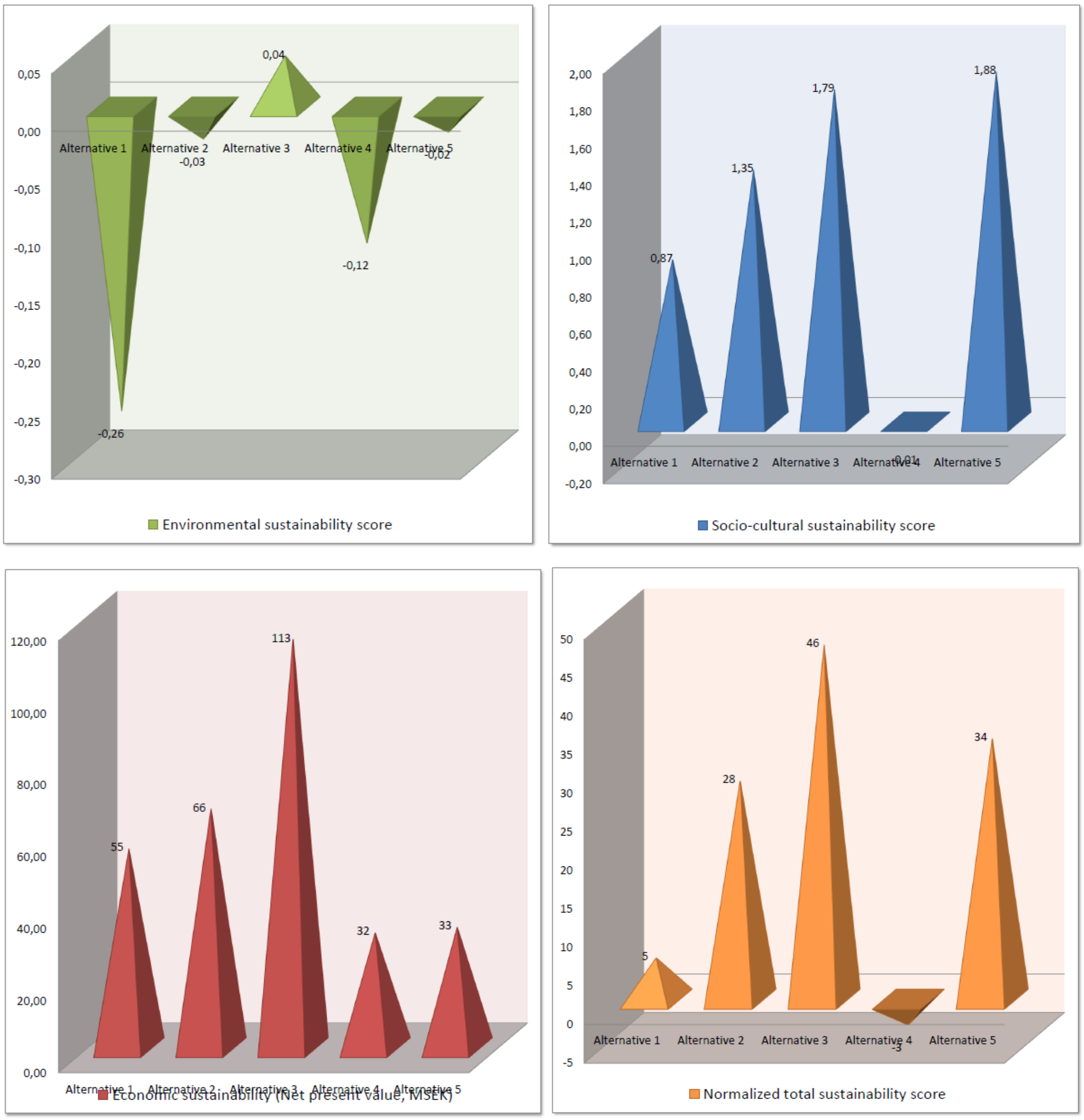


Figure 6-3 Economic sustainability, Environmental sustainability score and Social sustainability score and Normalized Total Sustainability, for set 2 of alternatives (obtained from Chalmers University of Technology (2014)).

According to Figure 6-3, the net present value that measures the **economic sustainability** of alternatives in set 2 varies between 32 million of Swedish crowns (alternative 4, with values very close to the ones of alternative 5) and 113 millions of Swedish crowns (alternative 3).

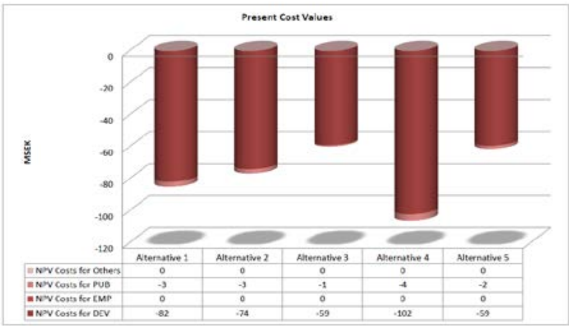
In set 2 all the alternatives show an **environmental sustainability** score close to zero, between - 0.26 and 0.04, being alternative 1 the less favorable, followed by alternative 4. Alternative 3 shows a slightly positive environmental sustainability score.

Social sustainability score is positive to all the alternatives in set 2, varying between 0.01 and 1.88. Alternative 4 has the lowest score and alternative 5 the highest, followed by alternative 3.

The **normalized total sustainability score** varies between – 3 (alternative 4) and 46 (alternative 3) within the scale of normalization between -100 and +100. Alternatives 2 and 5 have scores of 28 and 34, respectively. Therefore, to all the alternatives, except for alternative 4, there are more positive than negative effects. Alternative 3 is the only alternative with positive result in all the three domains, whereas alternative 4 is the most unfavorable or 2nd most unfavorable alternative in all domains.

All the alternatives have strong sustainability on domain level, meaning that there is no compensation between the different domains. On the other hand, no alternative has strong sustainability on the key criteria levels, thus some criterion with a negative performance are compensated by positive impacts in another(s) key criterion(a).

Continuing to look at the Economic effects of Alternatives in Set 2, a Distributional Analysis of the Present Cost Values and the Present Benefit Values is shown, respectively on the left side and on the right side of Figure 6-4.



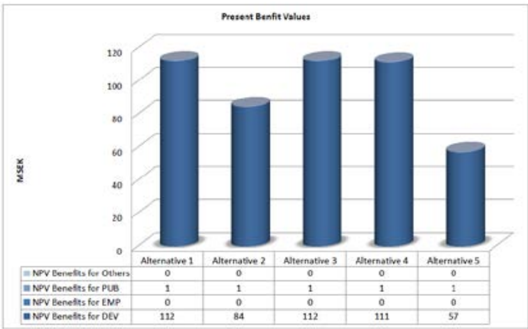


Figure 6-4 Distribution of the NPV costs and NPV benefits among the different stakeholders. Set 2 of alternatives (obtained from Chalmers University of Technology (2014)).

As it can be seen in Figure 6-4, both benefits and costs are concentrated on the developers. Other parts than the developers also have benefits and costs. In fact, some of the zeros are not true zeros, as the values from Table 6-4 are rounded when presented in Figure 6-4.

6.4 Uncertainty and Sensitivity Analysis

Figure 6-5 shows the normalized total sustainability SCORE with uncertainty intervals, applied to set 2 of alternatives. The probability distribution for sustainability indices for each of the alternatives is shown in Figure 6-6.

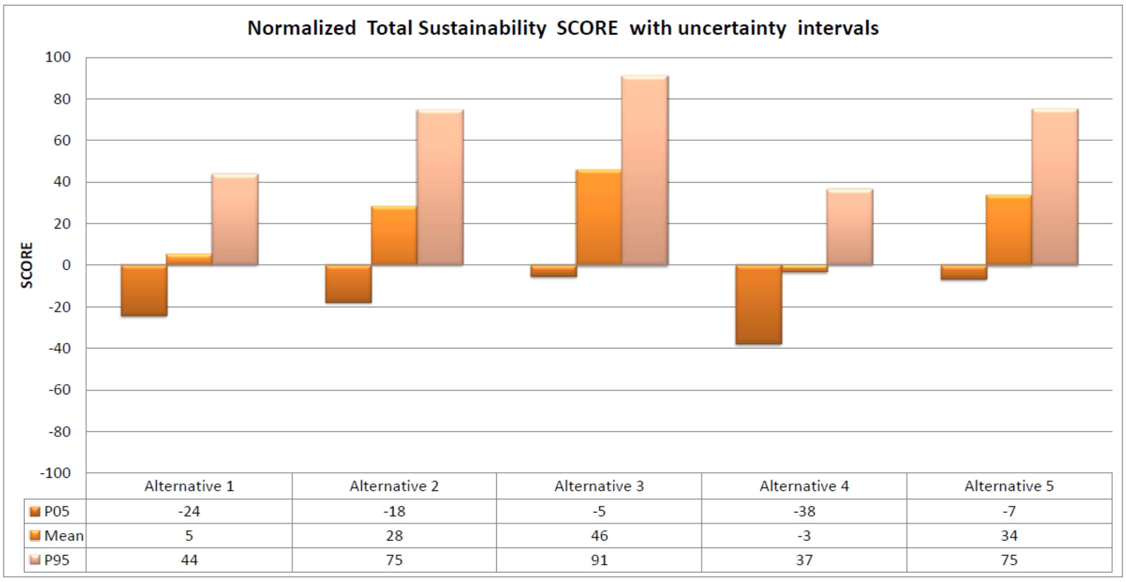


Figure 6-5 Normalized Total Sustainability. Inclusion of uncertainty interval. Set 2 of alternatives (obtained from Chalmers University of Technology (2014)).

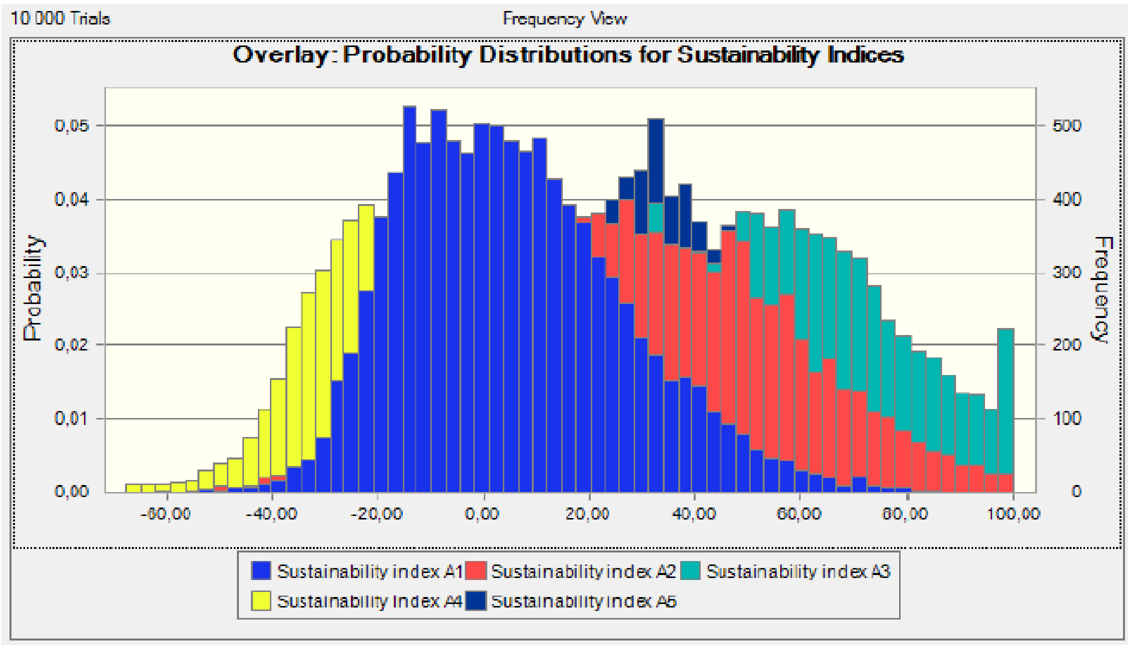


Figure 6-6 Probability distribution for sustainability indices for the five alternatives in set 2 (obtained from Chalmers University of Technology (2014)).

According to Figure 6-5 and Figure 6-6, alternatives 2 and 3 have the highest uncertainties and alternative 1 has the lowest uncertainty. On the other hand, the mean value in Figure 6-5 (which corresponds to the normalized total sustainability score presented in Figure 6-3) has its highest value in alternative 3 and its lowest value in alternative 1. The uncertainty in the results of alternative 1 includes both positive and negative values, whereas the confidence interval of the alternative 3 focuses mainly in positive values, distributed between negative values close to zero and very high positive values.

Figure 6-7 illustrates which items or criteria/sub-criteria most influence the end result of the MCA to set 2 of alternatives.

Figure 6-7 Sensitivity analysis for the five alternatives in set 2 (obtained from Chalmers University of Technology (2014)).

For all the alternatives, one criterion from the economic domain (B1) is the one affecting the result the most, contributing to increase SCORE. Most of the other criteria to which the calculations are sensitive to, are from the environmental domain, which also contribute increasing SCORE. The social domain is also represented in alternatives 1, also leading to increase in SCORE. For alternatives 2, 5 and especially for alternative 3, the result is sensitive to the economic criterion C1d, contributing to the reduction of the SCORE value.

7 Discussion

This chapter discusses the development of Fixfabriken case-study, assesses the application of SCORE, and suggests adjustments in the tool to enable its future application to other type of processes.

7.1 Case-study

At the stage of **generation of alternatives** of urban redevelopment in Fixfabriken, there is a great level of **uncertainty** both regarding the urban redevelopment and the remediation options that are suitable to the site. During the period of this master thesis, some options regarding the planning process in the case-study site changed, namely the intention of what to do with the tram hall. Furthermore, more detailed investigations of the contamination at the site are not taken into account on this work. This new data can affect the selection of alternatives, especially of remedial actions.

If the assumptions assumed change significantly, then the results might change considerably also. During the study, different assumptions were tested thus obtaining different results.

7.1.1 Assessment of economic domain

A challenge in the assessment of the alternatives is that the alternatives include a **lot of combinations of remediation and redevelopment possibilities**, which makes the evaluation more complex.

For both set 1 and 2 of alternatives, the **economic sustainability is evaluated only considering the monetized cost and benefit items**. For Fixfabriken case-study, it was **possible to monetize 37,5% of the benefit items (3 out of 8) and 43% of the cost items (8 of 14)** of the items that are included in the economic domain of the SCORE tool. The no-monetized benefits items that are not part of the calculations correspond to items that are likely not to be important or only somewhat important, and therefore possibly with low influence on the final results. On the contrary, no-monetized cost items includes, among others, items that are expected to be considered as very important, thus been able to have a significant influence on the results, namely on the scoring of the sustainability of the alternatives and even on its ranking. This is possibly the case of items C1f and C2c.

The **results obtained to the economic domain are very dependent on the assumptions** made when conducting the CBA as well as **its uncertainties**. For Fixfabriken case-study, the benefit item with the highest likeliest value is by far "B1. Increased property values on site". Even considering the benefit items that are not monetized, B1 is still the most significant. This item is considered to have a high uncertainty, thus being likely to affect the final score of the alternatives if assumptions are to be changed. Looking at the costs side in Fixfabriken case-study, the cost item "C1d. Remedial action" has by far the highest likeliest value. Once again, even when comparing with the no-monetized cost items, the C1d is by far the most significant. This item also has a very high uncertainty, as a lot of assumptions are made.

Some aspects that are part of the regeneration alternatives were **not included** in the economic analysis, namely the **demolition works** of the existing buildings and infrastructures, **and the construction works** of new ones. Furthermore, the approach adopted doesn´t allow distinguishing between different **densities of construction**, both building footprint and height of the builldings. Therefore, it can be considered that both the total benefits and costs due to the redevelopment of the case-study site are underestimated, as there are **no specific items for the redevelopment itself**. Due to the high level of uncertainty, and without additional calculations, it is not possible to guess if the total NPV in the economic sustainability would be higher or lower than the one calculated and shown in Figure 6-1 and Figure 6-3, respectively in Section 6.3.1 and Section 6.3.2.

In the CBA calculations, the size of the site influences significantly the monetization of some items. Due to the uncertainty of exactly which areas are going to be intervened, for example, excavated, and to reduce the complexity of the analysis of the results, **simplifications are done**, by assuming that that all the 4 parts of the site have the same size. Furthermore, excavations are done to the same depth all over the site, although different in set 1 and set 2.

The case-study Fixfabriken is not consistent with the current practice of using the tool SCORE, as described in Section 3.2.5.

When performing the **CBA to set 1 of alternatives**, a negative sum of NPV is obtained to all the alternatives, with the lowest value in alternative 3, and the highest value with alternative 5, closely followed by alternative 1.

Looking at the interval of the final values, it can be said that the difference of values between the 5 alternatives is very significant. This reflects the different options both of remediation and of urban redevelopment in each of the alternatives, by keeping or changing the existent buildings and infrastructures. The unfavorable results for alternatives in set 1 are mostly due to what ended up to be revealed as unadjusted remedial options, specifically the treatment train solution. This is elucidative of the caution that is needed when developing a case-study based on the methodology of another case-study, as different local conditions and assumptions probably lead to different optimal solutions, namely of the remediation to consider. It is also extremely dependent on the costs of remediation and on the amount of soil considered to be handled.

Some comments can be made to the results obtained for the different alternatives:

- Alternative 1 and 2 are very much alike, except the future land use in Fixfabriken factory area. Whereas alternative 1 assumes residential use in all the area, alternative 2 assumes that half the area becomes a green area. The only difference in the monetization of the items is in benefit item B1, which becomes lower in the alternative 2.
- On a first approach, alternative 3 and 4 seem to be the less favorable. However, when comparing these alternatives with the remaining 3 alternatives, it has to be considered that these alternatives 3 and 4 are the only ones with remediation and new construction occurring in all the 4 areas. This leads to a highest value in the cost item C1d due to the mobilization of a significant greater volume of soils.

- When comparing alternative 3 with alternative 4, the remediation approach is the only difference between them. The less favorable value to Alternative 3 might be a consequence of less extent monetization of the benefit items compared with the cost items. Furthermore, the costs with the remediation and treatment train on-site are higher than the saving with less contaminated soil being transported off-site. This results from the specific soil conditions assumed, namely the fraction distribution of the soil and the fractions considered to be efficient for the treatment train chosen. All this has to do with the high uncertainty. It might also reflect that the sieving and soil washing that are part of the treatment train chosen are not efficient or economically feasible, and that other treatment train / remediation approach should be considered. The excavation of a layer of soil with an average of 3 m thick is probably generating a very huge amount of soil to handle that affects the costs significantly.

Finally, it is worth to mention that the identification of costs with the remediation is quite simplified. As so, costs with the improvement of the indoor-air quality in alternative 5, by implementing measures such as active / forced ventilation are not quantified, although the cost to do that is not likely to be significant. Furthermore, the sieving and soil washing costs are included, but a previous stage that is probably necessary to deal with the chlorinated solvents in Fixfabriken factory is not monetized. This is likely to affect the cost, although it can be assumed that it will occur in all the alternatives. Therefore, this is not likely to change the ranking of the alternatives in the economical domain, although the values are expected to be more negative.

When performing the **CBA to set 2 of alternatives**, a positive sum of NPV at the economic domain is obtained to all the alternatives, except for alternative 5. Alternative 3 is the one with most interesting social profitability, followed by alternative 1.

In the assessment performed, it might be considered that the positive values are somehow “overestimated” due to the influence of the benefit item B1. Looking at the magnitude of the final values, it can be said that the difference of values between the 5 alternatives is very significant. This reflects the different options both of remediation and of urban redevelopment in each of the alternatives, by keeping or changing the existent buildings and infrastructures, and by removing or leaving the soil as it is.

Some comments can be made to the results obtained for the different alternatives:

- Alternative 3 appears as the most favorable alternative, as the options to deal with the remediation of the site revealed to be the ones with the lowest cost. At the same time, alternative 3 is one of the alternatives with a highest extent of residential areas as future land use, thus resulting in a high NPV on the benefit items side.
- Alternative 5 is scored with the lowest value as new residential future land use is confined to only one of 4 areas of the site, thus resulting in a lower NPV.
- Alternative 1 and 3 are interesting to compare to assess how much a different remediation approach affects the assessment of the alternatives, concluding that the traditional dig and dump might not be the most favorable comparing with on-site possibilities of both acting on the contaminant source and on the contaminant pathways. Uncertainties regarding the local conditions, the suitability of the

solutions and assumptions, as well as the costs of the remediation, advise for caution when making these judgments for a specific site, such as to this case-study.

In set 2, an attempt is done to include and quantify costs with the possibilities of remediation considered. However, such costs are not site-specific and probably have deviations. Variations can be on the unitary costs side, as realized when consulting available literature, and on the assumptions side.

When **comparing the outcome from the CBA performed to set 1 and set 2 of alternatives**, results obtained are not easily comparable as different assumptions and different options of redevelopment, including the remediation, were taken into consideration, resulting consequently in important differences in the NPV, specially on the cost side.

The most significant assumption is the amount of soil to manage when proceeding with excavation, which depends on the site conditions, namely spreading of contamination in the soil, and construction requirements, such as the area to be intervened, here assumed to be 2,5 ha per part of the site. In set 1, a layer with an average of 3 m is considered to be excavated, whereas in set 2 that layer has an average thickness of 1,5 m. This reduces significantly the excavation costs for the alternatives in set 2. It is extremely uncertain if this adjustment provides a more realistic assumption. Nevertheless, it shows the importance of setting assumptions as much as possible close to the reality. Besides C1d, it also affects C2b and C3b. Furthermore, adjustments in the sub-method of some specific items, namely C1d, C1e and C3b also affect the results, although not so significantly.

Despite it is not possible to clearly compare the alternatives from different sets, the following can be stated. The only difference between alternatives 4 from set 1 and from set 2 is the thickness of the layer of soil to excavate. The result from the CBA is of – 73.86 millions of Swedish crowns for alternative 4 from set 1 and of 6.03 million of Swedish crowns for alternative 4 from set 2, which reflects the influence in the costs of the amount of soil to handle. It is therefore expected that all the alternatives in set 1 would have a higher performance if the amount of soil to handle would be considered of lower amount. Still, the remediation approaches in set 2 seem to be more sustainable than the treatment train chosen in set 1.

7.1.2 Assessment of environmental and social domain

As the result from the CBA was not favorable for set 1 of alternatives, a qualitative assessment of the environmental and the social domains was not carried out.

When assessing the environmental and social domains to alternatives in set 2, it comes that the case-study site is assessed as a whole area instead of 4 different areas as done for the economic domain. In certain items, negative punctuation is balanced by positive punctuation, being the score written a balance of those, thus making it difficult to understand the meaning of a scoring of a certain main item or sub-item.

7.1.3 Result of case-study

Attention must be paid when looking at the results. The values presented are obtained from probability distributions calculated by Monte Carlo simulation for each of the domains and when combining the 3 domains and calculating the sustainability SCORE. Therefore, alternatives with similar scores in each domain, and at the end the normalized total sustainability SCORE must be considered with precaution. For instance, alternatives 4 and 5 in set 2 in the economic assessment should be considered equivalent.

The results obtained for set 1 of alternatives show that the alternatives assessed are not worth of consideration.

From set 2 of alternatives, several alternatives seem worth like to be proposed, although one can be highlighted. Alternative 3 is the one that most likely is the most favorable in set 2, closely followed by alternatives 5 and then 2. On the other hand, alternative 4 is most probably the less interesting of the set. The alternative in the top of the ranking is not likely to change if the weight of the different domains is changed, as alternative 3 shows the highest score in environmental and economic domain and is very close to the top score in the social domain.

Furthermore, it needs to be taken into account that uncertainty can misjudge the sustainability of the alternatives, discarding eventually alternatives that could be interesting if assumptions were set correctly. In fact, similar solution with different assumptions lead to very different results, such as NPV in alternative 4 from set 1 and 4 from set 2 which are very different.

As mentioned, there is a large uncertainty in the assumptions done. A decrease of the uncertainty can be achieved by asking the stakeholders for more information (size of the areas to intervene), by getting expert judgment (soil fractions, remedial approaches including technical solutions and costs, property value) and additional data about the soil conditions (field investigations), to name the most important ones. Some information provided or methodologies suggested very recently by the stakeholders (costs with field investigations, property values) are not considered in this report due to time constraints. Otherwise, it could decrease the uncertainty of some of the benefit and cost items. Any adjustments will affect the results, in different ways depending on the specific items.

Regarding the future stages of the development of the plan and implementation of the project, some reflections are now done regarding the remediation possibilities. Considering some literature available, and the opinion of some experts consulted, soil washing is not adequate to deal with chlorinated solvents, namely trichloroethylene and some hydrocarbons. In fact, this treatment technology poses problems with air quality during handling of soil contaminated with volatile compounds, in open air (such as TCE). As so, a first step of in-situ treatment might be more suitable, followed by excavation and, depending on the soil fractions, sieving and soil washing. In-situ approaches that might deal with the volatile compounds are in-situ thermal desorption, soil vapor extraction. Soil flushing and in-situ chemical oxidation are also possibilities.

7.2 Evaluation of the SCORE tool

Case-study Fixfabriken as part of the research project Balance 4P brought possible to experience the use of the SCORE tool, therefore allowing the evaluation when using it to land use planning processes in early stages, and when looking at the outcomes obtained.

Some comments on the CBA within SCORE are also appropriate.

7.2.1 CBA within SCORE

Not taking into account the results of the non-monetized items might be problematic if there are many items not monetized, especially when it happens more in one of the sides: the cost side or the benefit side, or if there are items not-monetized classified as very important items. This affects scoring and even maybe the ranking of the alternatives.

7.2.2 Feedback from the user and from stakeholders for existing situation

Case-study Fixfabriken as part of the research project Balance 4P allowed experiencing the use of the SCORE tool, as user (author) and as recipient of the outcomes (stakeholders that participated in the workshops arranged by Balance 4P). Their perspectives are presented here.

From a **user perspective, who experienced the full use of the tool** (the author of this master thesis) as it is, it can be said:

- The **tool is easy to use**. Both diagrams that are self-explanatory and help menus of different types, as well as the SCORE Guide and Manual, provide guidance to the user along the several steps (Chalmers University of Technology, 2014) (Anderson, 2014);
- A **significant amount of information and data is necessary** as input in the application. Therefore, it is suitable for processes in a more advanced stage of development and not so much in early stages, as significant amount of information is likely to be available in the first;
- When not detailed data is available, the **uncertainty of the results** might be significant;
- SCORE is able to include the **assessment of a number of alternatives up to 5**. Despite in some situations this might seem too short, this is easily surpassed by selecting and assessing new alternatives through the iteration process that is defined in the methodology of SCORE itself. This ended up to be done to Fixfabriken case-study;
- SCORE is set to assess a certain site with common characteristics along the site itself. However, prior calculations allow considering several parts within the site, therefore enabling the assessment of the whole site, once again, as done in Fixfabriken case-study;
- When monetizing the economic domain, transparency and objectivity are gained;

- SCORE has still some part of subjectivity, when weighting each criterion that are part of the environmental and social domains, and when doing the appreciation of each criterion when scoring it. Attribution of scores is dependent on the expertise and previous experiences of the evaluator. Furthermore, weight given to each domain is also dependent on the particular concerns and perspectives of the users. On the other hand, this makes it useful to test different perspectives of several stakeholders;
- Score of some sub-criteria of environmental and social domains have compensation of negative and positive effects in the sub-criteria itself;
- When the process includes redevelopment of brownfields, simultaneous change in land use and different approaches to deal with site contamination might make it difficult to take conclusions.

Additionally, it can be mentioned that **SCORE tool should allow**:

- Personalizing the designation of the alternatives when defining the alternatives. For instance in Fixfabriken case-study, it is useful to mix letter and number to easily see which alternatives are more similar to each other.
- A good understanding of the results, being advisable to adjust the outcome in all the graphs, so that values are expressed not to the unit but to decimal or centesimal, otherwise values lower than 1 will always appear as 0. At the present, this is the case of most of the graphs and tables expressed in NPV, in millions of Swedish crowns, namely the distributional analysis of present costs and benefits values for the different stakeholders, that might mislead when interpreting the results.

A **recommendation to future users** is that, when assessing the economic domain, more effort should be put on the items classified as very important. Furthermore, focus on items that are likely to have a higher cost or benefit item value, NPV, therefore influencing more the results and the rankings of the alternatives, is advisable. This is because the economic sustainability is evaluated only considering the monetized cost and benefit items, as the no-monetized items are not part of the calculations, which is a limitation when looking at the result, especially when the non-monetized items included items identified as important.

Experienced users or experts should be part of the assessment team when performing the assessment and use of SCORE.

The **feedback from stakeholders** is worth of register. In the workshop hold in 13th of October 2014, organized by Balance 4P, the representatives of the municipality of Gothenburg had the opportunity to hear how the process of applying SCORE tool to Fixfabriken case-study went. Despite the interest of having an assessment of different alternatives at such an early stage, the stakeholders considered that too much effort is put into it, especially considering the significant uncertainty of the outcomes obtained. The stakeholders agreed that less demanding approaches seem to be more promising to be used in early stages of urban development.

7.3 Contributions for the application of SCORE in early stages of planning

So far, SCORE has been applied to remediation projects, see Chapter 3, in particular Section 3.2.5. As suggested in Figure 7-1, it can be considered that this tool has additional potential applications to support decision-making in other scopes.

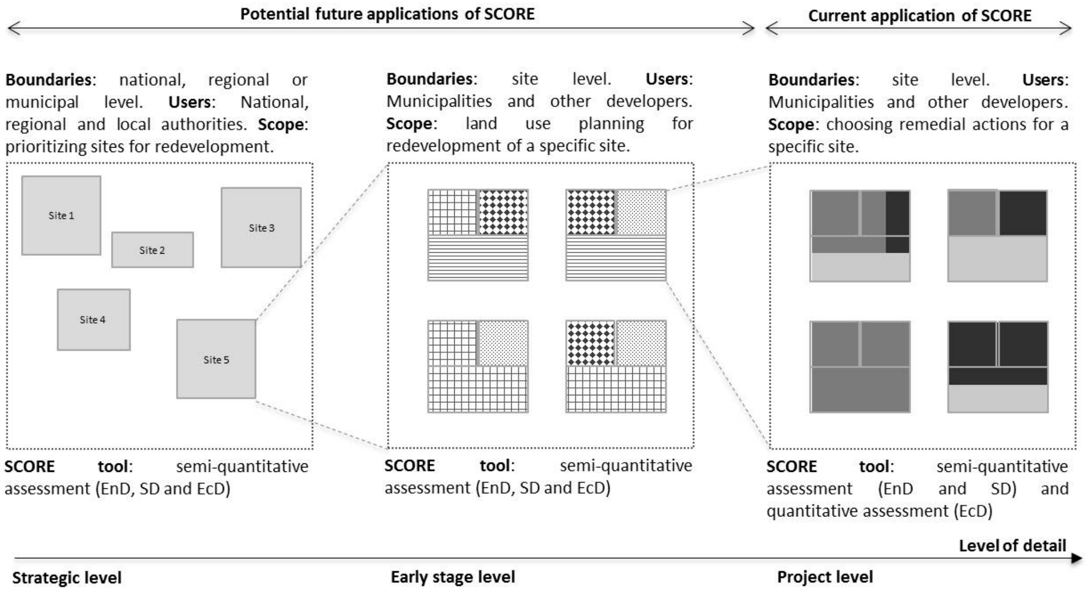


Figure 7-1 Current and potential additional applications of SCORE, with EnvD – environmental domain, SD – social domain, EconD – environmental domain (own illustration).

Time, human and monetary resources are scarce, and many underused and / or contaminated areas exist. Therefore, defining which sites within a vast territory should be intervened first, and not only which alternatives should be undertaken for a specific site, could be a field of application to SCORE (left side of Figure 7-1). At the middle of Figure 7-1, application to assess different possibilities of redevelopment of a chosen site is considered, including mainly land use planning, and possibly general considerations about the remedial strategy. Finally, in the right side of Figure 7-1 is shown the current application given to SCORE, focused on remediation projects in a specific site. Fixfabriken site is in a land use planning stage, though the tool applied in the case-study is developed for assessment of alternatives for remedial actions.

In the next sub-sections, some contributions to allow the application of SCORE to projects of urban brownfield redevelopment in early stages are presented. Focus is given to the economic domain, thus environmental and social domains won't be considered in these suggestions.

The adjustments suggested are of two types: changes in the cost and benefit items in the economic domain, to allow assessment of urban redevelopment and not only remediation, see Section 7.3.1; changes in the type of assessment of the economic domain, to facilitate its application to earlier stages of planning, see Section 7.3.2.

7.3.1 Incorporation of additional items

In order to allow application to SCORE tool to redevelopment projects, additional activities need to be included. Figure 7-2 presents an adaptation of the current conceptual model of SCORE. Demolition and/or construction works that are part of a redevelopment project are suggested as additional activities, in the bottom part of the figure. Remediation is kept in the model, as remedial actions are normally an important part of urban brownfield redevelopment projects.

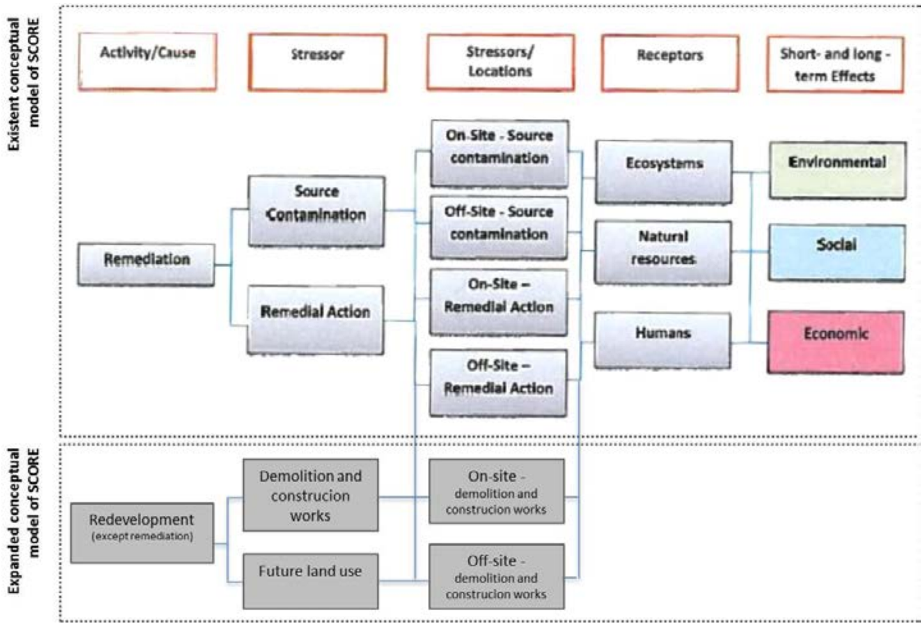


Figure 7-2 Conceptual model of an expansion of SCORE, adapted from Rosén (2014) in Volchko (2014)

Those new activities require additional and adjusted items, thus allowing integrating the new activities in the assessment undertaken within SCORE.

For the economic domain, the benefit item B1 can be adjusted to reflect the increase of the property value after all the redevelopment. On the cost side, a new item can be included, to reflect the cost of the demolition and the construction works. This can be done by keeping using the CBA method or by adjusting the method as suggested in Section 7.3.2. Additional considerations about these suggestions are also mentioned in Section 7.3.2 of the report.

7.3.2 Adjustments of the economic domain assessment

A simplification of the economic domain assessment seems advisable to potentiate the application of SCORE to early stages of urban redevelopment of brownfield areas. Therefore, the replacement of the CBA by a semi-quantitative method is suggested here.

Figure 7-3 shows the existent key-criteria for each of the domains (on the top), and suggests new key-criteria for economic domain (on the bottom), thus allowing the replacement of the CBA by the semi-quantitative assessment.

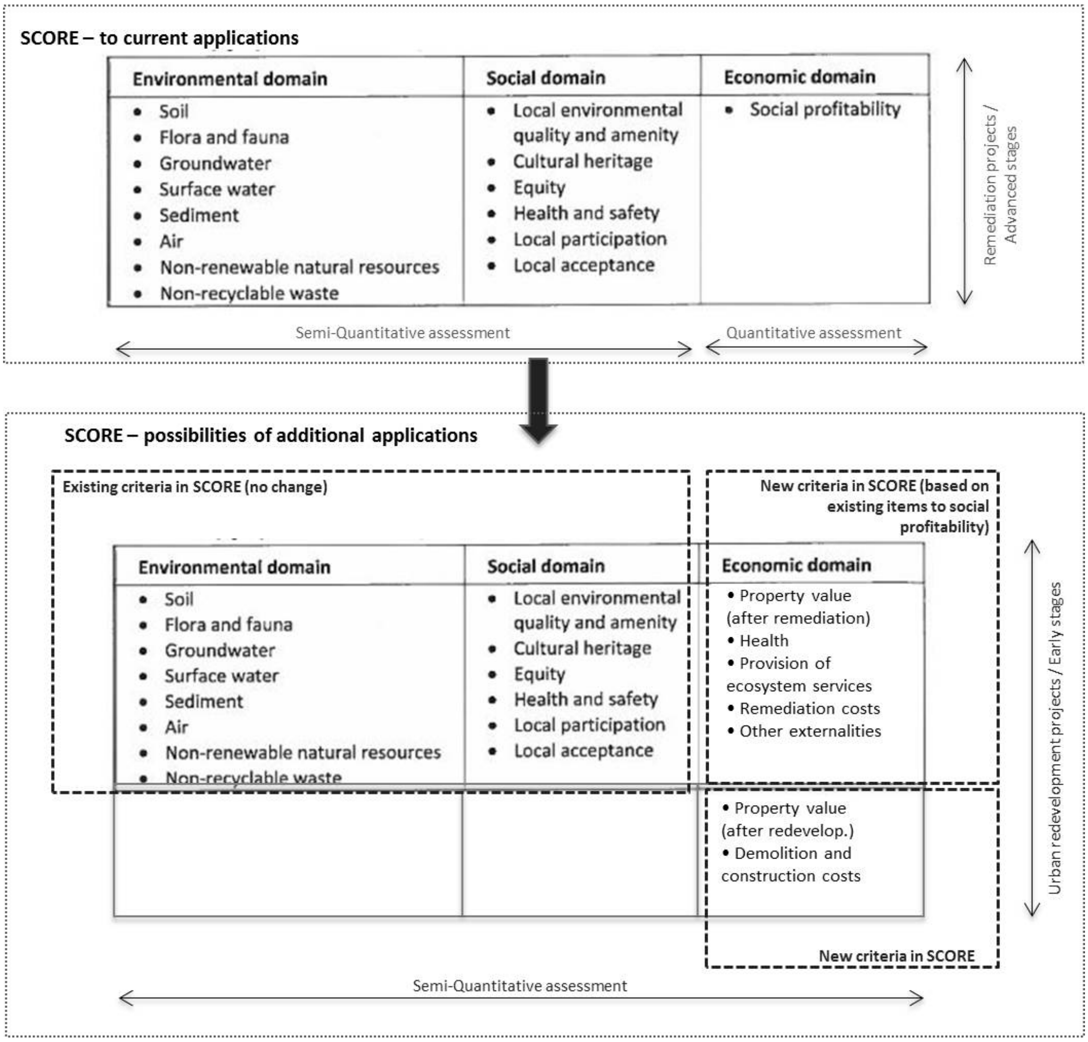


Figure 7-3 Key performance criteria for each sustainability domain in SCORE, to advanced stages (on the top) and to early stages of urban planning (on the bottom), adapted from Rosén (2014) in Volchko (2014).

The majority of the key criteria suggested to the economic domain corresponds to the type of cost and benefit items nowadays included in the CBA that is part of SCORE. To allow the assessment of activities that are specific from redevelopment interventions others than the remedial works, two additional key-criteria are included in Figure 7-3. Probably additional ones can be identified.

The suggested criteria could then be integrated in a new excel spreadsheet in SCORE tool, as suggested in Table 7-1, for proceeding with the semi-quantitative assessment of the economic domain in SCORE. The structure of the spreadsheet is the same as the one used for the environmental and socio domains, where the range, the score and the uncertainty of each criterion have to be defined. On the other hand, the key criteria suggested are based on the cost and benefit items that presently support the CBA that is part of SCORE. B1 key criterion is an expansion of the benefit item B1, and C5 key criterion is a completely new criterion, not based on any item from the CBA.

Table 7-1 – Economic Sustainability Assessment matrix for a semi-quantitative assessment in earlier stages of urban redevelopment of brownfield areas (own illustration based on Chalmers University of Technology (2014))

Step 5: Economic Sustainability Assessment

Assign distribution type, expected score, and uncertainty about your estimation for each sub-criterion. Scores are relative to the reference alternative.

Source Contamination (SC) - The removal of source contamination

Remedial Action (RA) - The remedial action itself

Construction works (CW) - The demolition and construction works for the redevelopment itself

		Alternative i		
Key criteria	**Sub-criteria**	**Range**	**Score**	**Uncert.**
B1. Increased property values after redevelopment due to SC + CW [Guide]	B1. Increased property value on site			
B2. Improved health due to SC [Guide]	B2a. Reduced acute health risks			
	B2b. Reduced non-acute health risks			
	B2c. Other types of improved health, e.g. reduced anxiety			
B3. Increased provision of ecosystem services due to SC + CW [Guide]	B3a. Increased recreational opportunities on site			
	B3b. Increased recreational opportunities in the surroundings			
	B3c. Increased provision of other ecosystem services			
B4. Other positive externalities than B2 and B3 due to SC + CW [Guide]	B4. Other positive externalities			
C1. Remediation costs due to RW [Guide]	C1a. Costs for investigations and design of remedial actions			
	C1b. Costs for contracting			
	C1c. Capital costs due to allocation of funds to the remedial action			
	C1d. Costs for the remedial action, including possible transport and disposal of contaminated soil minus possible revenues of reuse of contaminants and/or soil			
	C1e. Costs for design and implementation of monitoring programs including sampling, analysis and data processing			
	C1f. Project risks			
C2. Impaired health due to the remedial action due to RW [Guide]	C2a. Increased health risks due to the remedial action on site			
	C2b. Increased health risks due to transports to and from the remediation site, e.g. transports of contaminated soil			
	C2c. Increased health risks at disposal sites			
	C2d. Other types of impaired health due to the remedial action, e.g. increased anxiety			
C3. Decreased provision of ecosystem services on site due to RW [Guide]	C3a. Decreased provision of ecosystem services on site due to remedial action, e.g. reduced recreational opportunities			
	C3b. Decreased provision of ecosystem services outside the site due to the remedial action, e.g. environmental effects due to transports of contaminated soil			
	C3c. Decreased provision of ecosystem services due to environmental effects at the disposal site			
C4. Other negative externalities than C2 and C3 due to RW [Guide]	C4. Other negative externalities			
C5. Demolition and construction costs due to CW [Guide]	C5a. Demolition costs			
	C5b. Construction costs			

Table 7-2, Table 7-3, Table 7-4 and Table 7-5 provide a suggestion of guidance to some of the key-criteria part of the semi-quantitative approach to the economic domain, as proposed in this master thesis.

Key criterion B1. Increased property values after redevelopment is relevant to on-site effects with respect to removal of source contamination and construction works (Table 7-2).

Table 7-2 – Scoring guide to the Key criterion B1. Increased property values after redevelopment due to removal of source contamination and construction works (own illustration based on Chalmers University of Technology (2014))

Very negative effect: -6 to -10	**Negative effect: -1 to -5**	**No effect: 0**	**Positive effect: +1 to +5**	**Very positive effect: +6 to +10**
Significantly decrease of property values after redevelopment	**Decrease of property values after redevelopment**	**No change in property values after redevelopment**	**Increase of property values after redevelopment**	**Significantly increase of property values after redevelopment**
Example: -Extensive violation of remediation practices and of the redevelopment good-practices.	Example: -No fulfillment of remediation neither of redevelopment good-practices.	No improvement.	Example: -Site contamination levels comply with future land uses. Fulfillment of redevelopment good-practices.	Example: -Site contamination levels comply with future land uses. Fulfillment of redevelopment good-practices. -Construction of high quality / high level standards. Mixed uses, valuing residential uses over industrial ones. -Buildings in height

Key criterion B2b. Reduced non-acute health risks is relevant to on-site effects with respect to removal of source contamination (Table 7-3).

Table 7-3 – Scoring guide to the Key criterion B2b. Reduced non-acute health risks due to removal of source contamination (own illustration based on Chalmers University of Technology (2014))

Very negative effect: -6 to -10	**Negative effect: -1 to -5**	**No effect: 0**	**Positive effect: +1 to +5**	**Very positive effect: +6 to +10**
Substantial increase in non-acute health risk levels	**Increase in non-acute health risk levels**	**No effects on non-acute health risk**	**Reduction of non-acute health risk levels**	**Substantial reduction of non-acute health risk levels**
Example: -High contamination in the site or existence of carcinogenic contamination sources located in an uncontaminated portion of the site without protection, causing substantially increased non-acute risks for human health. Levels don't comply significantly with the guideline values for the future land uses. Number of users of the site in the future is very significant. -No decrease of the carcinogenic contamination of the site and simultaneously significant increase of the number of users in the site.	Example: -Contamination in the site or existence of carcinogenic contamination sources located in an uncontaminated portion of the site without protection, causing substantially increased non-acute risks for human health. Levels don't comply with the guideline values for the future land uses. Number of users of the site in the future is non-negligible. -No decrease of the carcinogenic contamination of the site and simultaneously increase of the number of users in the site.	Example: -No change in the carcinogenic contamination of the site.	Example: -Reduction of carcinogenic contaminant concentrations and carcinogenic contaminant mass in the site. -Cutting the exposure pathway of carcinogenic contaminants allowing reduction of exposure to users. -No change in the carcinogenic contamination of the site and simultaneously decrease of the number of users in the site.	Example: -Substantial reduction of carcinogenic contaminant concentrations and carcinogenic contaminant mass in the site. -Cutting the exposure pathway of carcinogenic contaminants allowing reduction of exposure to users.

Key criterion C1d. C1d. Costs for the remedial action, including possible transport and disposal of contaminated soil minus possible revenues of reuse of contaminants and/or soil, is relevant to on-site effects with respect to the remedial works (Table 7-4).

Table 7-4 – Scoring guide to the Key criterion C1d. Costs for the remedial action, including possible transport and disposal of contaminated soil minus possible revenues of reuse of contaminants and/or soil, due to removal of source contamination (own illustration based on Chalmers University of Technology (2014))

Very negative effect: -6 to -10	**Negative effect: -1 to -5**	**No effect: 0**	**Positive effect: +1 to +5**	**Very positive effect: +6 to +10**
Very substantial costs for the remediation.	**Substantial costs for the remediation.**	**No remediation costs.**	**Not applicable**	**Not applicable**
Example: -Intensive remedial works -Need to handle a significant amount of contaminated soil and transport it to landfill for industrial wastes -Very complex geological conditions and extent spreading of the contamination	Example: -Less intensive remedial works, with lower spreading of the contamination and lower concentrations of contaminants	Example: -No remedial action -Costs of remediation are balanced by benefits in using soil remediated to refill on site.	Not applicable	Not applicable

Key criterion C5b. Construction costs due to CW is relevant to on-site effects with respect to construction works (Table 7-5).

Table 7-5 – Scoring guide to the Key criterion C5b. Construction costs due to construction works (own illustration based on Chalmers University of Technology (2014))

Very negative effect: -6 to -10	**Negative effect: -1 to -5**	**No effect: 0**	**Positive effect: +1 to +5**	**Very positive effect: +6 to +10**
Substantial construction costs in the site.	**Some construction costs in the site.**	**No construction costs in the site.**	**Not applicable**	**Not applicable**
Example: -Intensive construction works, with buildings footprints with high % of the property size and with buildings with several floors height.	Example: -Less intensive construction works, with buildings footprints with low % of the property size and with buildings with few floors height.	Example: -No construction works.	Not applicable	Not applicable

7.3.3 Additional steps

So that the contributions previously presented can be applied in early stages of urban redevelopment in brownfield areas, further work is necessary, namely:

- Reflection about potential conflict between criteria of different domains, namely if eventual double-counting occurs when assessing;
- Identification of potential additional criteria for economic domain;
- Development of guidance to all the key-criteria of the economic domain;
- Operationalization of the new approach for the economic domain in the SCORE tool, with further testing in existing case-studies, such as to Fixfabriken site, and comparison with the method used so far;
- Feedback from the main stakeholders to assess its user-friendliness.

As mentioned before, these reflections attended only the economic domain, thus being necessary to ponder the need of adjustment of the key-criteria in the environmental and the social domains.

The need of new key-criteria or adjustments in the existent ones should be based on an inventory to make about the key criteria linked to assessment of sustainability in urban redevelopment of brownfields, as previously done for the assessment of the sustainability of remedial actions (Brinkhoff, 2011).

7.4 Additional comments

Changing economic domain assessment from a CBA to a semi-quantitative approach can be advisable whenever the data available is scarce and the interventions are not defined in detail, for urban planning processes and even for remediation projects, in early stages.

Adjustments in SCORE and future application to redevelopment process seem to make sense when the process to assess has no negligible contamination issues.

On the other hand, the decision to carry out or not these adjustments in the SCORE tool should be taken based on the answer to the following question: Does it solve a lack in the present available tools of assessment for urban brownfield redevelopment? Additional literature review on this specific issue should therefore be carried out.

8 Conclusion and Recommendations

This final chapter presents the conclusions of the work performed and suggests recommendations.

During the work performed during this master thesis, it was possible to combine very different assessment methods, and integrate the three domains of sustainability, the environmental, social and economic ones, into the outcomes of the MCDA approach adopted by using the SCORE tool.

The application of the MCDA based tool **SCORE**, designed and tested to assess alternatives of remediation projects, to a case-study of brownfield urban redevelopment in an early stage of planning, allows to evaluate the suitability of the tool to these kind of processes. Focusing on the economical domain, different types of constraints appear when applying it to these processes: 1) too much uncertainty in these early stages, thus conducting to outcomes with a low reliability to be used in decision-making; 2) too much effort when performing the CBA, which makes the tool not much attractive to potential users and require some level of expertise.

Nonetheless, by proceeding with some adjustments, as suggested, the tool has the potential to be expanded to other applications. Specifically to urban brownfield sites early planning stages of the redevelopment, the replacement of the CBA as a quantitative method by a semi-quantitative method seem promising in making the process more agile. At the same time, adding or adjusting cost and benefit items in the CBA or in the suggested semi-quantitative method enables assessing the effects of the redevelopment itself.

The contributions suggested in this master thesis require further investigation to confirm the possibility of the proposed approach. It is therefore recommended that a literature review of the key performance criteria for sustainable urban redevelopment is made, that the suggestions are implemented in the tool, that further test in case-studies and comparison with previous assessment is assured, as well as stakeholders are listened.

Once succeeded, the tool will contribute to more sustainable decision-making in a critical area in nowadays society. The relevance of this is dependent on the absence of similar tools (or not), thereby enhancing the relevance of the expansion of the SCORE tool.

Regarding the specific **case-study** assessed, Fixfabriken site, it is clear that the data available and considered in this master thesis, as well as the land use planning options considered, are still unsufficient or undefined to obtain outcomes capable of supporting decision-making. On the contrary, the assessment can lead to the exclusion of alternatives due to less inadequate assumptions to the site. Nevertheless, the assessment is valuable.

If a more realistic outcome would be intended to the site, it is recommended that the assumptions are adjusted / validated as much as possible, to reduce the degree of uncertainty, through additional data, expertise, experience from stakeholders. Scoring of the criteria with the participation of the stakeholders is likely to increase the compliance of the project to the requirements along the process.

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10 Appendices

10.1 Appendix economic domain. Item “B1. Increased property value on site”

10.2 Appendix economic domain. Item “B2b. Reduced non-acute health risks”

10.3 Appendix economic domain. Item “C1c. Capital costs due to allocation of funds to the remedial action”

10.4 Appendix economic domain. Item “C1d. Costs for the remedial action, including possible transport and disposal of contaminated soil minus possible revenues of reuse of contaminants and/or soil”

10.5 Appendix economic domain. Item “C1e. Costs for design and implementation of monitoring programs including sampling, analysis and data processing”

10.6 Appendix economic domain. Item “C2b. Increased health risks due to transports to and from the remediation site, e.g. transports of contaminated soil”

10.7 Appendix economic domain. Item “C3b. Decreased provision of ecosystem services outside the site due to the remedial action, e.g. environmental effects due to transports of contaminated soil”

10.8 Appendix environmental domain: weighting, scoring and motivation, for each criteria

10.9 Appendix social domain: weighting, scoring and motivation, for each criteria