



**KTH Industrial Engineering
and Management**

Industrial Ecology Methods within Engagement Processes for Industrial Resource Management

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Licentiate Thesis in Industrial Ecology

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ABSTRACT

The global use of resources such as materials, energy, and water has surpassed sustainable levels by many accounts. The research presented here was explicitly normative in its aim to improve the understanding of, and make sustainable change toward highly systemic issues of resource management. The core methods chosen to work toward this aim were bottom up action research procedures (including stakeholder engagement processes) and industrial ecology analysis tools. These methods were employed and tested in pragmatic combination through two of the author's case study projects. The first case study, performed between 2009 and 2012, employed a multi-stakeholder process aimed at improving the cycling of construction and demolition waste in the Stockholm region. The second case study produced a strategic tool (Looplocal) built for facilitating more efficient regional industrial resource networks. While the highly participative aim of the cases required a larger contribution of resources than that of more closed studies, it is arguable that the efficacy of approaching the project aims is improved through their employment.

Keywords

Resource Management, Recycling, Stakeholder Participation, Industrial Symbiosis, Construction and Demolition

PREFACE

I would like to be quite clear that my research is normative and that my licentiate¹ work was centered on instigating change toward more benign societal material cycles. Given the goal oriented research approach, I believe describing my personal goals and how these are related to the construction and performance of my research to be an apt starting point. But first, bear with me as I extend this narrative with some personal history.

I grew up close to nature in the Ozarks of the Midwest United States. Here I learned the joys of watching tadpoles grow into frogs and the magic of letting one's imagination run wild in the woods. I also saw the impacts humans could have on the environment quite early on when the process of eutrophication slowly turned my clear swimming hole into a green weedy mess. However, I didn't go on to study biology or ecology; I studied business during my bachelor's education. After graduation and some years of work and travel, I was not satisfied with my ability to create positive change in environmental problems, which were increasingly vexing my thoughts. I wanted to do something that would reduce the *negative* impacts of human production and consumption on society and the greater environment. I believed that I could be more effective by using my business skills and working for change from 'within the system' as opposed to what I saw as the alternative of working directly against 'the system'. Interestingly, this licentiate has brought me full circle to analyze, among other things, from a social science framework these assumptions of how change occurs in larger systems. This work is fundamentally a direct extension of the search for tools to better understand and effectively move toward that personal aim of 'reducing the negative impacts...'.

“Oj” – as the Swedes would say. I was naïve to what this journey would entail!

I began my research by looking into impacts on industrial sustainability, what lie behind them, and how to handle them. This entailed mostly descriptive research, which looked at issues such as eutrophication from pulp and paper production or particle emissions from coal incineration – and what technologies could eliminate or greatly reduce impacts from these activities. It was exciting to see the improvements many of these sustainable technologies had made and could make. There are many

¹ A licentiate in Sweden is an academic degree at the graduate level corresponding to approximately half a doctoral degree. The work of a licentiate can be presented as a dissertation manuscript or as a compilation thesis. I have chosen to write a compilation thesis. Such a thesis is led in with a summarizing chapter (a 'kappa') and followed by a compendium of articles. The intent of the kappa is to sum up - and to some extent analyze, integrate and reflect upon - the results in compendium.

amazing technologies available for improving the sustainability of our society (according to such social, economic, environmental and cultural pillars).

I believe the importance of involving various stakeholders in the processes of implementing these technologies and actions is paramount. This participative imperative is often central in how we research, interpret, and work to improve our industrial systems and general ways of life. Through collective engagement, scientific inquiry, policy creation, dinner table conversation - I believe we can increase our potential for digging deeper into problems that vex us; sometimes overturning assumptions of how things are, and how things 'ought to be' along the way to our new arrangements of living - our steps toward sustainable futures.

I deeply enjoyed the opportunity to investigate areas so close to my desires of supporting a continued healthy and vibrant planet; and I very much hope I may continue in this line as I persist to straddle the lines between scientist, facilitator and activist.

ACKNOWLEDGEMENTS

I would like to begin by thanking the Ragnar Selllbergs Foundation for its support of this Licentiate research. The foundation put its trust in my judgment and gracefully allowed me to explore the diverse issues that the research uncovered along the way. I hope my research has in its own way worked toward addressing the goals of the founder - Ragnar Sellberg - regarding his concerns for the Earth's health and our common need for environmental protection.

I would like to wholeheartedly thank my group of supervisors at the department of Industrial Ecology: Associate Professor Nils Brandt, Professor Ronald Wennersten, Docent Maria Malmström, and Adjunct Monica Olsson, Docent Fredrik Gröndahl, among others. While I was well supported by all in this group and in the department on a continual basis, I would like to especially thank Nils Brandt for his extra efforts, patience, and insights over the four years of this work as well as David Lazarevic and Jorge Zapico for their frequent input and review during the research process. Also, I would like to give a special thanks to the internal reviewer and all those who helped push my work through under (too often) pressing time schedules.

As for the industrial half of my industrial doctorate, I was taken in from day one as part of the team at Ragn Sells AB, and I am very grateful for the companionship, guidance, and real Swedish working spirit that I was imparted with while working at this company. There are too many great colleagues to name, but I would like to especially thank those of the Raw Material and Entreprenad groups for their support and friendship.

Without the input of the many stakeholders in my projects there would not have been any great participative aspect to the research. I am greatly appreciative of their time (both in and out of workshops), as well as for their patience with my coming to terms with new social methods and even a new language. A more extensive list of these stakeholders can be found in Paper II.

Regarding Paper III and the Looplocal project, I wholeheartedly thank Mariya Lysenkova for her many hours of pro bono programming as well as Bianca Sayan and Niklas Smedberg for their support in the project.

Finally, I would like to thank my family and friends - those in the United States for their patience in letting me peruse such a long and far away dream - and my Swedish colleagues and friends for helping me to keep my feet on the ground and a smile on my face.

Graham Aid

Stockholm, Sweden 2013

LIST OF APPENDED PAPERS

Paper I

Aid, Graham, and Nils Brandt 2010, “**Action Research in Waste Management.**” In Proceedings of Linnaeus Eco Tech '10: The 7th International Conference on International Conference on Natural Sciences and Technologies for Waste and Wastewater Treatment, Remediation, Emissions Related to Climate, Environmental and Economic Effects. Edited by Kaczala, F., S. Arzur, I. Tjäder, and W. Hogland. Kalmar, Sweden, pp. 1009-1019.

The author was responsible for the planning of the project, undertaking of the engagement and communication processes including interviews and workshops, collecting data, performing systems analysis, and writing of the paper. The author also made an oral presentation of the paper at the conference.

Paper II

Aid, Graham, and Nils Brandt 2012, “**Improvement of Aggregate Cycles in Stockholm and the Baltic Region. Activities and Results of the BRA Initiative.**” In Proceedings of WASCON 2012: The 8th International conference on Sustainable management of waste and recycled materials in construction. Gothenburg, Sweden. Available from: ISCOWA Portal: Digital Library at <http://www.iscowa.org/>. [1 Dec 2012].

The author was responsible for the planning of the project, undertaking of the engagement and communication processes including interviews and workshops, collecting data, performing systems analysis, and writing of the paper. The author also made an oral presentation of the paper at the conference.

Paper III

Aid, Graham, Nils Brandt, Niklas Smedberg, and Mariya Lysenkova 2012, “**Looplocal – a Heuristic Visualization Tool for the Strategic Facilitation of Industrial Symbiosis.**” In Peer Reviewed Proceedings of GIN'12: The 18th Greening of Industry Network Conference. Linköping, Sweden. Available from GIN confex portal at <https://gin.confex.com/gin/2012/webprogram/>. [1 Dec 2012]

An updated version of Paper III has been submitted and is under revision for a special journal issue.

The author was responsible for planning the project, design of the method, the collection of data, the analysis of results, and writing the paper. The author also made an oral presentation of the paper at the conference.

LIST OF ABBREVIATIONS

AR	Action Research
BRA	Bygg- och Rivnings-Avfall (Construction and Demolition Waste)
BIMMS	Baltic Inert Material Management Symposium
C&D	Construction and Demolition
CE	Conformité Européenne (European Conformity Marking)
CBA	Cost Benefit Analysis
DfE	Design for Environment
IE	Industrial Ecology
IS	Industrial Symbiosis
ICT	Information and Communications Technology
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
MCDA	Multi Criteria Decision Analysis
MFA	Material Flows Accounting
NACE	Nomenclature statistique des Activités économiques dans la Communauté Européenne (European industry classification system)

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1 INTRODUCTION

1.1 Resource (Mis) Management and Sustainability

The discourse surrounding the need for improved management of resources such as material, energy and water is not new. However, the issues pulled forward by the conservation movement in mid-20th century and articulated in literature such as *The Limits to Growth* (Meadows 1972) have been increasing their presence across the popular media and on local, national, and international political agendas in recent years. This contemporary increase in focus is partially due to relatively new collaborative efforts such as the Brundtland Commission (World Commission On Environment and Development 1987), The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005), and the Intergovernmental Panel on Climate Change's (IPCC's) assessments which highlight some of the impacts and challenges society faces in regards to our use of resources. It is estimated that humans are already overexploiting the carrying capacity of our planet, and that by 2050 a 100% overuse is predicted (WWF 2007). Reports, including those above, show interconnected effects from our unsustainable resource use (such as falling ecosystem service capacity, rapidly reducing stocks of scarce water and resource stocks, and climate change) as presenting great societal challenges. If we do not improve social, scientific and political understanding and action in regards to these challenges, the results of faulty resource management will not only continue to threaten the current and future generations' ways of life, health, or weather patterns; but this mismanagement can also directly threaten social and political stability. Indeed, conflicts over resources have already spurred quite a few wars with high human casualties in recent decades (Ross 2002; World Bank 2002).

The European Union took proactive steps to alleviate stresses from resource mismanagement in 2011 by establishing the "Roadmap toward a Resource Efficient Europe" (EC Environment 2011a) within which fundamental transformations of the European economy were called for. This communication calls for transformation of the economy by focusing on areas of 1) sustainable consumption and production, 2) turning waste into a resource, 3) supporting research and innovation, and 4) correcting harmful subsidies and market failures. The research presented herein focuses on "turning waste into a resource", as well as addressing issues of production and innovation.

1.2 Aim and Objectives of the *Kappa*

1.2.1 Aim

The work summarized in this *kappa* aims to improve resource management in regards to multiple perspectives of sustainability through the active employment of participative and analytical methods.

1.2.2 Objectives

The objectives of this thesis are to:

- A. Establish a framework for analyzing the use of industrial ecology tools within iterative and participative methodologies.*
- B. Demonstrate the use of a normative and participative research methodology for resource management.*
- C. Strategically select, employ, and display the results of industrial ecology analysis tools in facilitated cases.*
- D. Inspect some of the strengths and weaknesses of the bottom up and mixed method approach to normative research in the selected cases.*
- E. Investigate the potential for information analysis in strategically supporting the facilitation of resource efficiency initiatives by developing and presenting the results of a tool.*
- F. Tentatively analyze the impact of the normative grounding of the cases, and discuss some of the underlying assumptions in each of the cases.*

1.3 Research and Project Formation

This industrial licentiate¹ was funded by Ragnar Sellbergs Stiftelse in part for building upon the author's master's thesis work (Aid 2008) and the broad aim of investigating and improving construction and demolition (C&D) resource efficiency and cycles. This led to the selection and design of the first case described below. Later, continuing in the theme of "turning waste into a resource" and along with significant industry interest; this research was broadened to include material and energy efficiency initiatives between industries from outside the C&D area. This broadened research, looking at industry to industry recycling and resource efficiency, is presented in the second case.

¹ 50% of which was work in industry at Ragn Sells AB and 50% in university research

1.4 The Two Cases

1.4.1 The construction and demolition project (Papers I and II)

From 2008 until 2011 project BRA, *Bygg-och Rivningsavfall i Stockholms Län* [in Swedish] - *Construction and Demolition (C&D) waste in Stockholm County* [in English] - was coordinated from the division of Industrial Ecology, KTH. This project was focused on actively improving from plural perspectives the cycles of C&D materials (specifically non-metallic inert materials) in the Stockholm region. In response to the normative aim and the inter-systems complexity identified in early interviews, a highly participative action research procedure was adopted. Through processes of network communication, workshops, a course, and an international symposium - a number of issues (such as market development, recycled product quality, greenhouse gas impacts, collaborative planning, and statistics) were prioritized, researched, and acted upon. Indicators for measuring progress in selected areas were developed and preliminary action plans created. At a final co-organized symposium Swedish delegates laid the groundwork for the establishment of a Swedish C&D recycling branch organization. A general timeline of the project is given in Figure 1.

Papers I and II in this thesis summarize the procedural methodologies, analytical methods, activities, and results of the project. Paper I was published in 2010 after the initial preparation phases and the first two workshops. Paper II was published after the international symposium in late 2011.

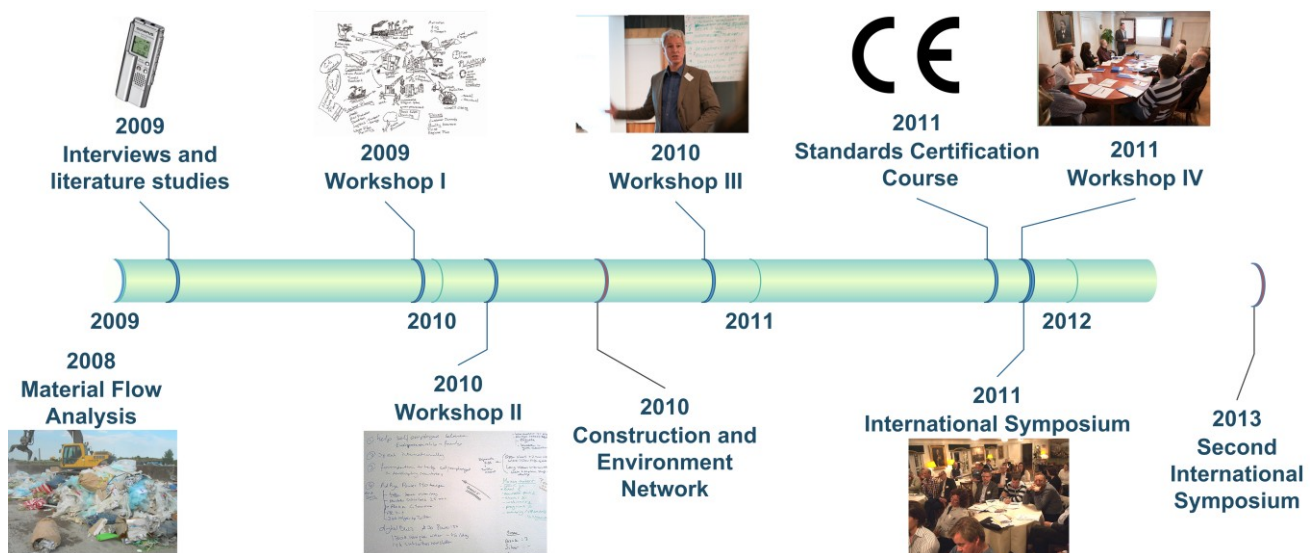


Figure 1- A Timeline of the Regional Project Dealing with Construction and Demolition Materials

1.4.2 Looplocal – Strategic support for industrial symbiosis facilitation (Paper III)

Industrial Symbiosis (IS) was explained concisely by Jensen et al. (2011) as “the establishment of close working agreements between normally unrelated industrial organizations that lead to resource efficiency”. The *study* of IS has been described as “... a process whereby materials, water, energy and informational flows between and among companies are investigated with the objective of developing and improving co-operative links between/among them” (Baas 2011). These links are often within local or regional spatial scales. Additionally, many IS studies differentiate between *self-organized*, *planned* (such as a new industrial zone planning), and *facilitated* networks (Paquin and Howard-Grenville 2012).

In 2011 collaborative masters’ thesis works looking to facilitate Industrial Symbiosis in the northern Stockholm region (Hemmer 2011; Smedberg 2012) identified a few challenges for actively facilitating industrial symbiosis in such industrial disperse regions. One challenge was to better identify which strategic regions to invest facilitative resources (money, time, energy). Another major challenge was identifying how to better pique potential (especially core) stakeholder interest. Looplocal, discussed in detail in Paper III is a data analysis tool that was consequentially built to strategically address these challenges. Figure 2 shows how the work with industrial symbiosis progressed from the two masters’ thesis works to workshops, to tool development, to tool testing and then to presentation within the community.

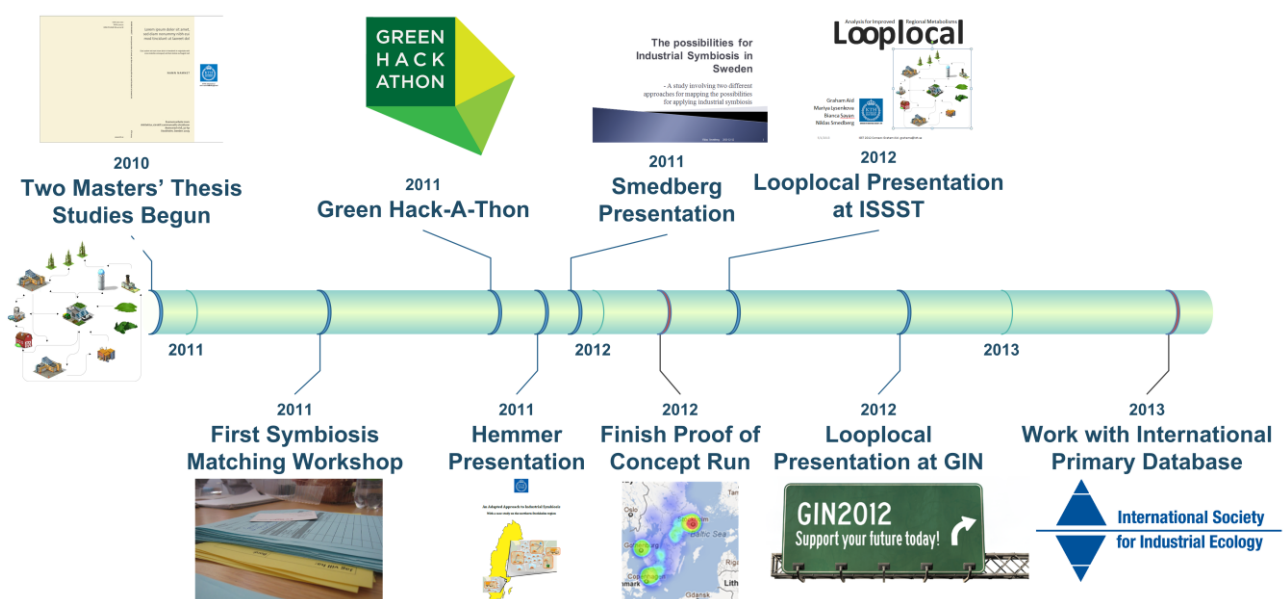


Figure 2 - A Timeline of Looplocal and Related Projects

2 THEORETICAL AND METHODOLOGICAL BACKGROUND

2.1 The initial selection of the procedural methodology and approach

Given a broad starting point, the approaches a researcher might choose from to investigate material intensive industrial systems and their resource management in general are quite wide. One could focus on technologies for cycling such materials (analyzing technical, environmental, and economic qualities). One could go deeper to develop and evaluate the various methods for such assessments. Alternatively one could analyze the processes of innovation or implementation of new more sustainable technologies into industry and wider society. Looking more toward this concept of ‘wider society’, one might take a broader perspective assessing the institutions, regimes, and socio-technical landscape within which technologies and resource management organizations are embedded. This list could go on into areas such as statistics, agency, cooperative methods, international case comparisons, or even philosophy. Often the inter-linkages between these areas are strong.

Stepping back to the issues discussed in the introductory section on resource management and sustainability, and focusing on the aims and objectives of the research, I made some critical decisions early on. The work would be done normatively and reflexively with the general aim of improving the sustainability of resource use, and this would be done in conjunction with the engagement of multiple stakeholders who held the potential to act upon the research, as not to perform systems analysis in a vacuum. Finally, this approach was chosen to take advantage of the experience in the field of industrial ecology with its basket of tools focused on bettering knowledge regarding the metabolism of human production and consumption systems. These requirements laid the groundwork for the procedural methodology and approach described in this thesis.

2.2 The Normative Foundation of the Research

When contrasting descriptive and normative research, it is often said that descriptive research looks at “what is” and normative research looks at “what ought to be” (Sabine 1912). The research activities presented and reflected upon in this licentiate are inherently normative in the respect to their macro ideals of catalyzing transitions in resource management toward multi-perspective notions of *sustainability*. Restated, this research actively strives to create *improvements* in relation to the resource dilemmas that society currently faces. As discussed, this normative background was essential in the choice of research approach and choice of following methods.

Some might argue that scientists risk quality and objectivity when moving toward normative work. There might arise a risk that the inclusion of personal ideals would lead to ‘bad science’. And indeed there are many areas a researcher’s personal values or norms can influence a research project, for example, in choosing area(s) of focus (Allenby 2006), procedural approach to a project, analytical method(s) (and their scoping), substitute or comparative systems, actors to be included, level of openness, etc. One method for dealing with this ethical and subjectivity issue is to be as openly transparent about the normative aims and formation of a research activity as possible. Another method for addressing the subjective issues is to add a participative – more democratic – core to such endeavors (Bell and Morse 2008; Reason and Bradbury 2007). I have endeavored to employ both of these methods to reasonable extents throughout this research.

2.3 Research Ontology and Paradigms

Regarding the taxonomies and terminology used when discussing research methods and methodologies applied in the cases, Crotty (1998 pg. 1) made clear that “...the terminology is far from consistent in research literature and social science texts. One frequently finds the same term used in a number of different, sometimes even contradictory ways.” I have followed the taxonomical framework laid out by Fien (2002) – see Table 1 - which involves defining research paradigms through their ontology, epistemology, methodology, and common research methods. Fien (2002) describes four broad paradigms for research approaches as being empirical-analytical, interpretive, critical, and post-structuralist¹. Fien (2002) then makes the further distinction between positivist empiricism and postpositive empiricism². I have extended this framework through the addition of another research approach - Pragmatism - to this taxonomy as shown in Table 1.

(Kinash 2006) defines a paradigm as “...a matrix of beliefs and perceptions. There are power relationships and action implications inherent in paradigms”. More specifically, “research paradigms comprise ‘the fundamental assumptions’ about ‘the general orientation to life, the view of knowledge, and the sense of what it means to be human’ that direct particular modes of inquiry” (van Manen 1990 pg. 27). Each paradigm has unique ontological, epistemological, and methodological dimensions. *Ontology* refers to beliefs regarding existence - what is real and true. Fien (2002) contrasts the various research paradigms’ ontologies by asking the question, “What is the nature of reality?” *Epistemologies* refer to beliefs of what can be known, and how valid knowledge may be

¹ Other researchers such as Johnson et al (2007) state only 3 typical research paradigms: Qualitative, Quantitative, and Mixed Method.

² Positivism is a type of empiricism, but not all varieties of empiricism are positivistic (Johnson and Onwuegbuzie 2004).

achieved. Epistemologies also deal with the relationship of the knower to the known (i.e. subjectivity and objectivity). Here Fien (2002) contrasts the various research paradigms by asking the question, “What is the nature of knowledge?” A *methodology* is a procedural approach to scientific inquiry specifying how research questions may be asked and answered. Kinash (2006) further defines ‘methods’ as, “*the techniques or processes we use to conduct our research*” and ‘methodology’ as, “*the discipline or body of knowledge that utilizes these methods.*” Finally, Fien (2002) utilizes the question, “*How is knowledge developed?*” to contrast the methodological positions of the various research paradigms. It is common for a paradigm to have several research methodologies, and for methodologies to share research methods (and sometimes even sub-methodologies), as shown in Figure 1. Pragmatism, as discussed in the next section readily employs methodologies from other paradigms. Figure 3 is the authors’ representation of how research paradigms may contain multiple procedural methodologies and how these methodologies may in turn hold a basket of methods or tools. The Pragmatic Paradigm is more apt to apply procedural methodologies from several (presumed distinct) research paradigms.

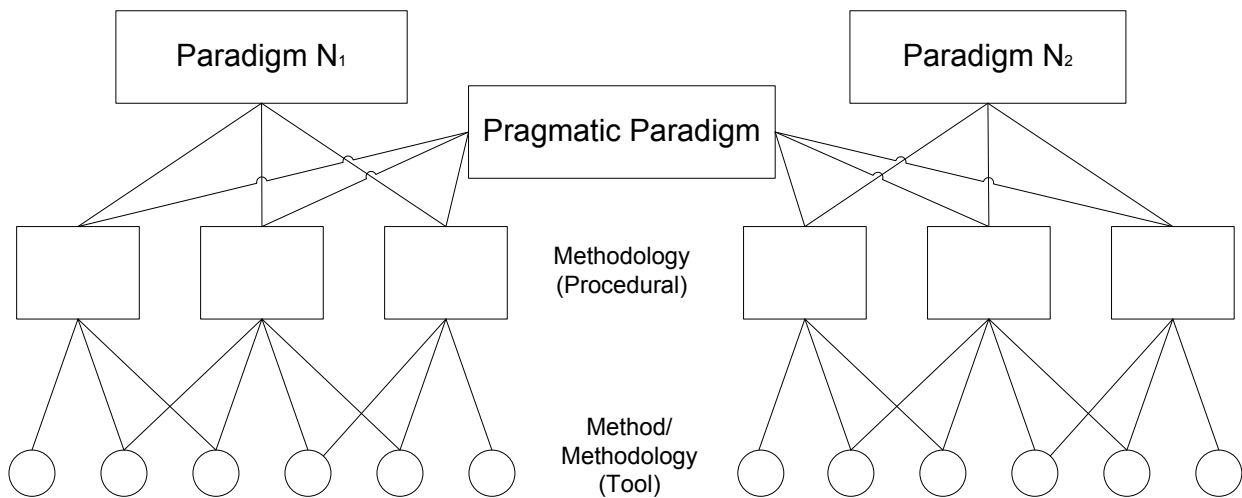


Figure 3 - A representation of how a paradigm may hold several methodologies and a methodology share methods with other methodologies. The pragmatic paradigm ventures to employ procedural methodologies from across other paradigms.

Table 1 - Taxonomy of Research Paradigms – (Adapted From Fien, 2002 with addition of the Pragmatic Research Paradigm by the author)

Research Paradigm	Ontology (What is the nature of reality?)	Epistemology (What is the nature of knowledge?)	Methodology (How is knowledge developed?)	Common research methods
Empirical–analytical 1 (positivism)	Reality is ‘out there’, it is an independent material reality waiting to be discovered. Generalizations can be made free of context	Knowledge can be objective and ‘untainted’ by values and other factors that may cause bias	Experts formulate research questions and then test them empirically under carefully controlled circumstances	Experiments
Empirical–analytical 2 (post-positivism)	Reality is 'out there' and independent of us, but we can never fully understand it. Generalizations can be made free of context	Objectivity is the ideal goal, but values and other factors can produce some bias if not regulated or controlled for	Knowledge grows from the gradual accumulation of findings and theories and testing the significance of relationships	Sample survey, Quasi-experimental pre-and post-test designs, Content analysis, Managerialist action research
Interpretivism / Constructivism	Reality is not 'out there'; it is conditioned by human experiences and interpretation. Reality is not independent but socially constructed and can have varied meanings	Knowledge is not objective but subjective. Knowledge is constructed through the interaction of the researcher and the objects of enquiry	Identification of the varied constructions or interpretations of reality that exists and an attempt to recognize patterns in them or bring them into some consensus	Ethnographic case study, Focus group, Phenomenography, Historical research
Critical	Reality is ‘out there’, it is material and independent of us, but we can never fully understand it	Knowledge is not objective but subjective. Values and power play a pivotal role in the construction of knowledge. Knowledge and issues of equity and power are closely intertwined	Research seeks to understand the practices and effects of power and inequality, and to empower people to transform environmental and social conditions	Action research, Soft systems, Critical ethnography, Collaborative enquiry, Critical semiotics
Post-structural	There are multiple, representations of reality constituted in and through language and discourse in different contexts	Events are understood in terms of powerful and subordinated discourses which constitute social realities	Research seeks to deconstruct or expose how dominant interests constructed through language and discourse preserves social inequalities and ecological harm	Discourse analysis
Pragmatic/ Mixed Method ¹	Absolute Truth (reality) is what will be the “final opinion” perhaps at the end of history. Lowercase “t” truths (i.e., the instrumental and provisional truths that we obtain and live by in the meantime) are given through experience and experimenting	Knowledge is viewed as being both constructed and based on the reality of the world we experience and live in	Individual researchers have freedom of choice to select procedures that best meet the needs of their problem situation	Various mixed methods from statistical and thematic analysis. What and how to research are based on intended use/ consequences

¹ Addition of the author based on (Johnson and Onwuegbuzie 2004)

Table 1 does not try to represent each research paradigm in full intricacy, but has simplified the defining attributes of each. As noted, the addition of the pragmatic/mixed method research paradigm to this table was the author's own. With the definitions from the next section this addition to the taxonomical table may seem a bit ironic given the deconstructive position of pragmatism toward research paradigms.

2.4 The Pragmatic Approach

2.4.1 The pragmatic approach in general

Pragmatism has been defined as “a deconstructive paradigm that debunks concepts such: as 'truth' and 'reality' and focuses instead on 'what works' as the truth regarding the research questions under investigation. Pragmatism rejects the either/or choices associated with the paradigm wars, advocates for the use of mixed methods in research, and acknowledges that the values of the researcher play a large role in interpretation of results” (Tashakkori and Teddlie 2003 pg 713). Thus said, the pragmatic research paradigm is atypical in regards to its level of prescription compared to other research paradigms illustrated in Table 1. While pragmatism as a philosophy has been in discussion since the late 19th century (see James 1898), its application to research paradigms and the clarification of mixed methods approaches is relatively recent. For in depth discussion of the latter application of pragmatism and its foundations see Teddli and Tashakkori (2008) and Crotty (1998).

Much research done within the pragmatic research paradigm is termed ‘mixed-method’ or ‘multi-method’ research. One can be said to be performing mixed method research when a combination of qualitative and quantitative methodologies, methods, concepts, or terminology are included in a single study (Teddli and Tashakkori, 2008). The fundamental aspect of mixed method research is placing the research question first. The combination of methods chosen should be those that offer the best chance to obtain useful answers to the research question at hand. According to this principle, “researchers should collect multiple data using different strategies, approaches, and methods in such a way that the resulting mixture or combination is likely to result in complementary strengths and non-overlapping weaknesses” (Johnson and Onwuegbuzie 2004 pg 18). For more on the fundamentals of mixed method research see Brewer and Hunter (2005). I suggest that this pluralistic, needs-based approach could be quite appropriate for use by normative researchers in pursuit of making sustainable change in multi-perspective contexts.

Such a mixing of methodologies from across research paradigms can be quite controversial as illustrated by Robottom and Hart's (1993) argument that research paradigms are incommensurate and “cannot be accommodated, as pragmatists would

like, at any level from methods to metaphysical” (Robottom and Hart 1993, pg. 16). Howe (1988 and 1992) looks further into this incompatibility thesis in regards to educational research. Howe admits, “Many educational researchers successfully go about their business unconcerned with the putative epistemological paradigm split” (Howe 1992, pg. 254). Howe adds to this that reflection on the debate can be a useful tool for a researcher to better understand the relationship of their research and practice.

2.4.2 The pragmatic, mixed method approach for the projects

By actively engaging diverse stakeholders in normative research projects, one does not only work toward addressing subjective bias, but inclusivity may also improve realism and momentum toward goals of action and change (Reason and Bradbury 2007). The subjectivity I was particularly interested in addressing with a participative approach to the cases was in relation to the notions of *sustainability* and *improvements*. When ideas of long term social, environmental, and economic flourishing are addressed; various people, organizations, groups and nations will have a wide collection of beliefs of what constitutes sustainability – and preferred paths toward such. This subjectivity can be both a hindrance and an enabler in engaging groups toward change (Brydon-Miller et al. 1993; Carman et al. 1994). In this thesis, I looked to leverage the enabling aspects of context dependency and subjectivity toward *improvements* in *sustainability*. In specific, I looked to enable action toward resource efficiency by giving a spread of regional stakeholders more active roles in framing, analyzing, and forming action plans. In essence, this approach follows the belief (not universally accepted) that actors are more likely to take action in processes that they own or have contributed actively (Reed 2008; Waterman et al. 2001; Zimmerman 1995). The assumed benefits of such an approach are not limited to stakeholder buy in, but may include potential for simplified or more relevant systems analysis, improved management for change, enhanced testing of assumption validity, and an overall better understanding of the ‘real world’ system and its salient aspects (Armitage et al. 2008; Berkes 2009; Phillipson et al. 2012).

2.5 Action Research Methods and Procedural Methodology

There are many types of engagement frameworks (procedural methodologies) available for normative participative ventures (Reason and Bradbury 2007). I employed the general principles and a selection of methods from the ‘action research’ (AR) discipline to a large extent in the BRA project, and more theoretically in the Looplocal project. After an extensive survey and reflection on the many definitions of action research, Waterman et al. (2001, pg. 4) defined action research as:

“...a period of inquiry, which describes, interprets and explains social situations while executing a change intervention aimed at improvement and involvement. It is problem focused, context-specific and future-oriented. ... The participatory process is educative and empowering, involving a dynamic approach in which problem identification, planning, action and evaluation are interlinked. Knowledge may be advanced through reflection and research, and qualitative and quantitative research methods may be employed to collect data. ... Theory may be generated and refined, and its general application explored through the cycles of the action research process.”

2.5.1 The fundamentals of action research

At the core of action research is the use of cycles of planning, action and reflection. Cycles which Lewin (1948) believed lead not only to new practical knowledge, but also lead to new abilities for creating knowledge. AR strives to create change by involving people in the 'planning and action', being flexible and responsive to the situation and actors, and achieving research mostly through following action with critical reflection (Dick 2002). The fundamentals of AR thus include (i) the concept of progressively focusing in, (ii) the action research cycle, and (iii) the reflective process.

2.5.2 The AR focusing in progression

The start of an AR process may be very unclear in regards to direction (fuzzy), but the design plan is for the questions, methods, and answers to become more precise as the cycles progress (see Figure 4).

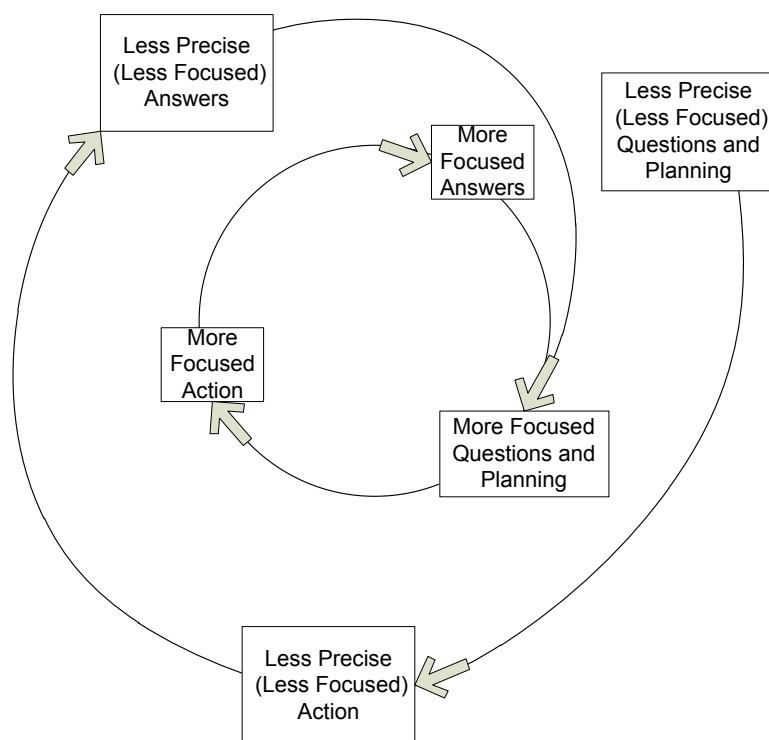


Figure 4 - The iterative focusing in progression of action research

One might start with an imprecise method to begin inquiry into an imprecise question and modify the approach as the question and its needs become more clear. A benefit of this design is that the research stays flexible, allowing for refining as the practitioner learns more about the situation and the problems it entails.

2.5.3 The action research cycle

One major principle of AR is the employment of iterative cycles of reflection, planning and action (Dick 1993). The cycle (as illustrated in Figure 5) is one version of many used to illustrate the nature of AR. For other constructions see Susman (1983 pg. 103) or (Hopkins 2008). For more on this process and methods see Paper II and Reason and Bradbury (2007).

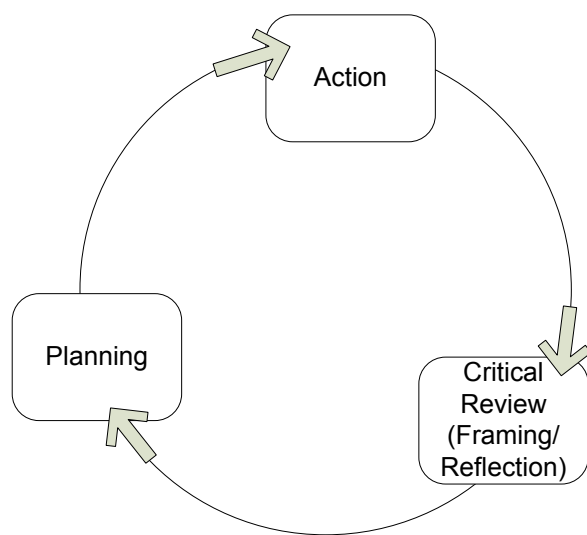


Figure 5 - The Action Research Cycle Consisting of Reflection, Planning and Action Stages – Adapted from Dick (1993)

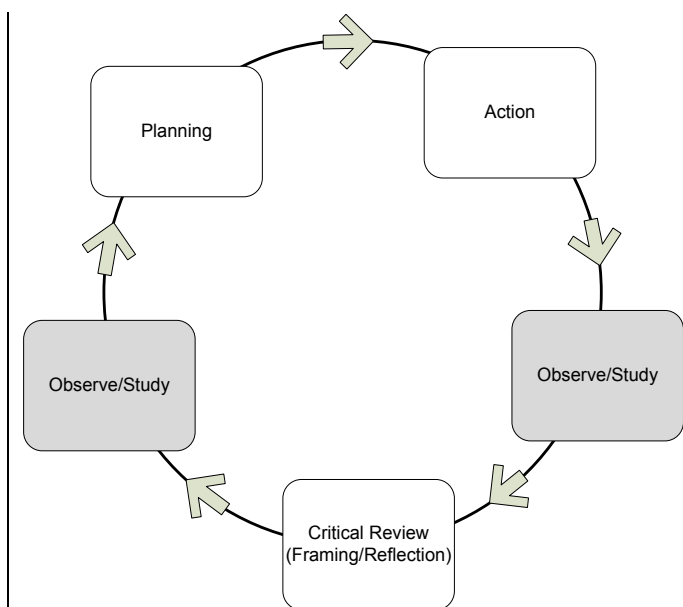


Figure 6 - The Action Research Cycle Unpacked for Analytical Use in This Licentiate

I unpacked the illustration of the AR cycle in Figure 6 to establish the case study framework which was utilized in this licentiate. This was done to underscore the acts of observing and studying which are often embedded in the planning and review/reflection steps. Therefore, as illustrated in Figure 6, I have pulled out the observing and studying steps. This is, in essence, a pragmatic combination of the critical and the post positivist methodologies described in Table 1. In this kappa, I utilized the framework in Figure 6 to clarify the application of tools from the field of industrial ecology in engagement processes. The field of industrial ecology is briefly explained in Section 2.6.

2.5.4 The action research fundamental of reflection

Perhaps the least clear step in the planning, action and reflection loop is reflection. Therefore, some additional explanation is given here. The reflection phase shown in Figure 5 and Figure 6 (also termed critical review) is an iterative step in many critical and empirical endeavors including the author's C&D project, as is shown later in Figure 10 and Figure 11. As the performance of reflection can be quite ambiguous, some work has been done to add structure to the process (Schön and Rein 1995). One way to structure the process of reflection is to divide the process according to levels of focus and context. Ardent (in Schön and Rein 1995) divided the various scales of which a topic of review or reflection might pertain into a 'ladder of reflection'. Moving up from situations at hand to meta-cultural frames along this ladder, shown in Figure 7, may assist one to consider their current project under various perspectives. This ladder was later used to structure part of the reflection in the discussion of this thesis in Section 5.4 - Beyond Transparency – Assumption Reflection.

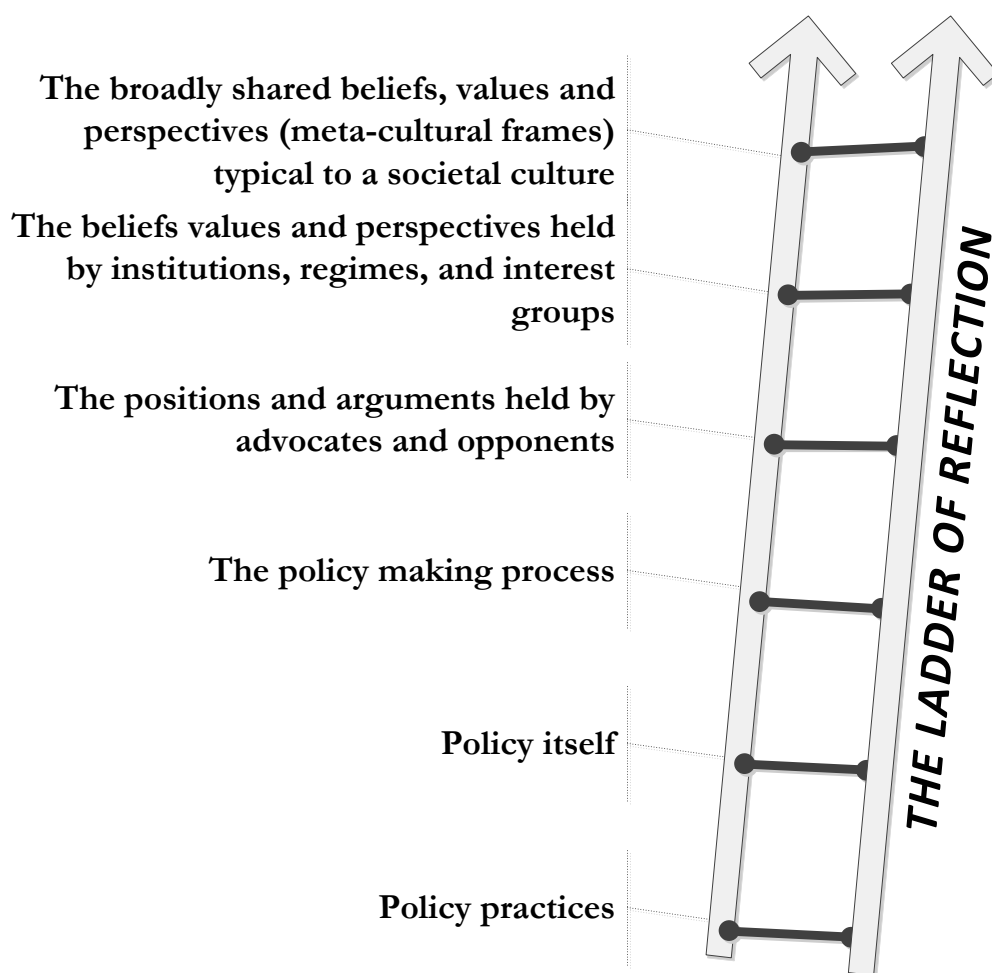


Figure 7 A depiction of the ladder of reflection - based on Ardent in Schön and Rein (1995, pg xiii) where moving up the rungs of the ladder lead to broader – more macro – levels of reflection

2.6 The Industrial Ecology Field – its research goals and methods

Throughout the duration of this research, I have been working as an industrial Ph.D. candidate dividing my work between market development activities at the Swedish waste management company ‘Ragn Sells AB’ and research at the division of Industrial Ecology at KTH. Industrial ecology is a relatively new field that seeks to analyze and strategically address among other things the metabolism of human production and consumption systems (Graedel and Allenby 1995). The term ‘industrial ecology’ was popularized by Frosch and Gallopoulos (1989).

Quite early on, industrial ecology took a wide systems perspective as shown by White’s (1994 pg. v) definition of industrial ecology:

“Industrial ecology is the study of the flows of material[s] and energy in industrial and consumer activities, of the effects of these flows on the environment, of the influences of economic, political, regulatory, and social factors on the flow, use and transformation of resources. The objective of industrial ecology is to understand better how we can integrate environmental concerns into our economic activities.”

The systems perspective and normative nature of the field was highlighted even further in the seminal textbook on industrial ecology by Graedel and Allenby (1995), where industrial ecology was defined as:

“... the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimize the total materials cycle from virgin material, to finished material, to component, to product, to obsolete product and ultimate disposal. Factors to be optimized include resources, energy and capital.”

Lifset and Graedel (2002) conceptualized the dual aspects of industrial ecology by dividing it into its analytical (theoretical) and its application oriented tools as shown in Figure 8.

On the left of Figure 8, methods such as material flows accounting (MFA), substance flow accounting (SFA), and life cycle assessment (LCA) could be used to study the use of resources in society. Next to these, cost benefit analysis (CBA), life cycle costing (LCC), and social life cycle assessment (SLCA) are tools which one might employ to improve knowledge of the social, and economic flows (and impacts) within said systems. These methods (on the left) lean toward the descriptive (as opposed to normative) side of science, however issues such as systems scoping, method choice, and indicator choice/weighting can impart subjective (and normative) aspects to these tools.

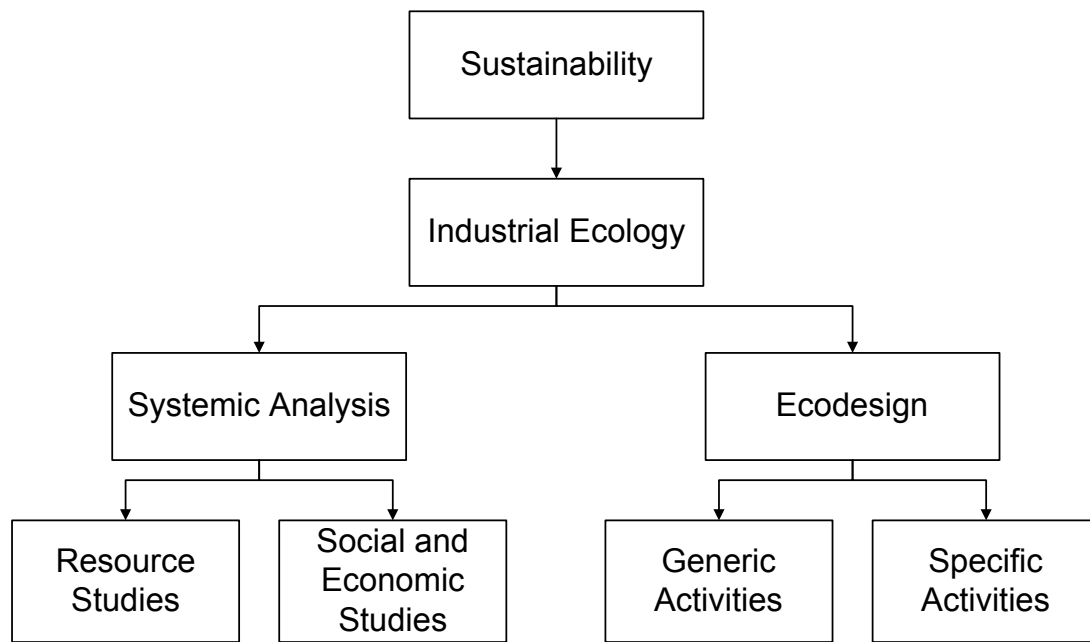


Figure 8 – Industrial ecology conceptualized in terms of its system oriented and application oriented elements – Adapted from (Lifset and Graedel 2002)

Some of the more design (application) focused activities of industrial ecology are shown on the right side of Figure 8. Here general activities such as Design for Environment (DfE) and Eco-Efficiency may be included alongside specific design projects. This methodological discussion of the cases in this thesis for the most part looks at the use of the systemic analysis tools from the left of Figure 8. The C&D project (Papers I and II) integrated MFA, LCA and CBA (of Systemic Analysis) into its process as described in Section 4.1. The second case (Paper III) utilized tools from both the systemic analysis (including LCA) and the ecodesign sides of industrial ecology.

3 PRAGMATIC METHODOLOGIES EMPLOYED IN THE CASES

Within this work I employed industrial ecology methods together with engagement processes in the two active case studies (the projects BRA and Looplocal). These were chosen specifically to address the challenges posed by resource and waste management in our contemporary industrial economies. The unpacked model of the action research procedural methodology (the action research cycle) introduced in Figure 6, is drawn upon to illustrate the methodological integration and use of industrial ecology tools within the projects facilitated by the author.

3.1 The C&D Case - Papers 1 and 2

In Swedish 'Bygg- och Rivningsavfall (BRA) stands for 'Construction and Demolition Waste'. In 2008, I completed a master's thesis work focused on such materials in the Stockholm region (Aid 2008). The thesis focused mostly on potential technologies for sorting and transforming (non-household) inorganic and organic materials into useful secondary products and fuels. Some 'screening' economic and environmental analysis of these technologies was also included. The technologies to improve (economically and environmentally) the resource management of such materials existed, so what would it take to implement them? This was a point of departure for the BRA project. After discussions and interviews with industrial actors in the construction and waste management branches it became clear that varying conceptions of market potential, inadequate long term planning, competition from cheap virgin materials, and other factors were prohibiting widespread implementation of wider systems' resource efficiency measures.

In order to further examine the hindrances toward efficiency and to continue on the normative path explained in the introduction; a multi-stakeholder procedure was established and embarked upon. With the EU's recent waste framework directive placing a target for member states to reuse or recycle 70% of C&D material (by weight) by 2020 as a foundation, (European Commission 2008) a group of stakeholders from branches such as construction, demolition, transport, waste management, local planning authorities, consultants, academics, housing authorities, etc., was collected. By the end of the project in 2012, the process had included four workshops, a certification course, and an international symposium. The whole process had brought the stakeholders to a point where they planned to continue the collaboration, research, and lobbying through a newly formed branch organization. These parts of the project are explained in detail in Papers I and II and a general timeline of the interviews, workshops and events is given in Figure 1.

3.1.1 Background to the methods of the BRA construction and demolition case

To analyze the use of industrial ecology methods in the BRA project I divided the analysis herein into that of the *macro* process – as shown in the timeline in Figure 1 and in Figure 11 – and into *micro* processes (spin off eddy-currents) embedded in the macro process. This is of course a simplification of the acts as they happened, but allows a structured analysis on macro and micro levels in accordance to the action research cycle framework of Figure 6. For more on these macro and micro processes see Papers I and II.

3.1.2 The use of methods in the macro process of project BRA

Many methods from both the industrial ecology toolbox, as well as the action research toolbox were employed in project BRA. The macro flow of project BRA is presented in Figure 9, including the various engagement phases of workshops, the CE (Conformité Européenne) standards course and the BIMMS symposium. An overview to the methods employed is embedded in each phase shown in Figure 9. See Papers I and II for the details regarding these methods and their implementation. The progressive use of methods in Figure 9 follows the general framework laid out and unpacked in Figure 6.

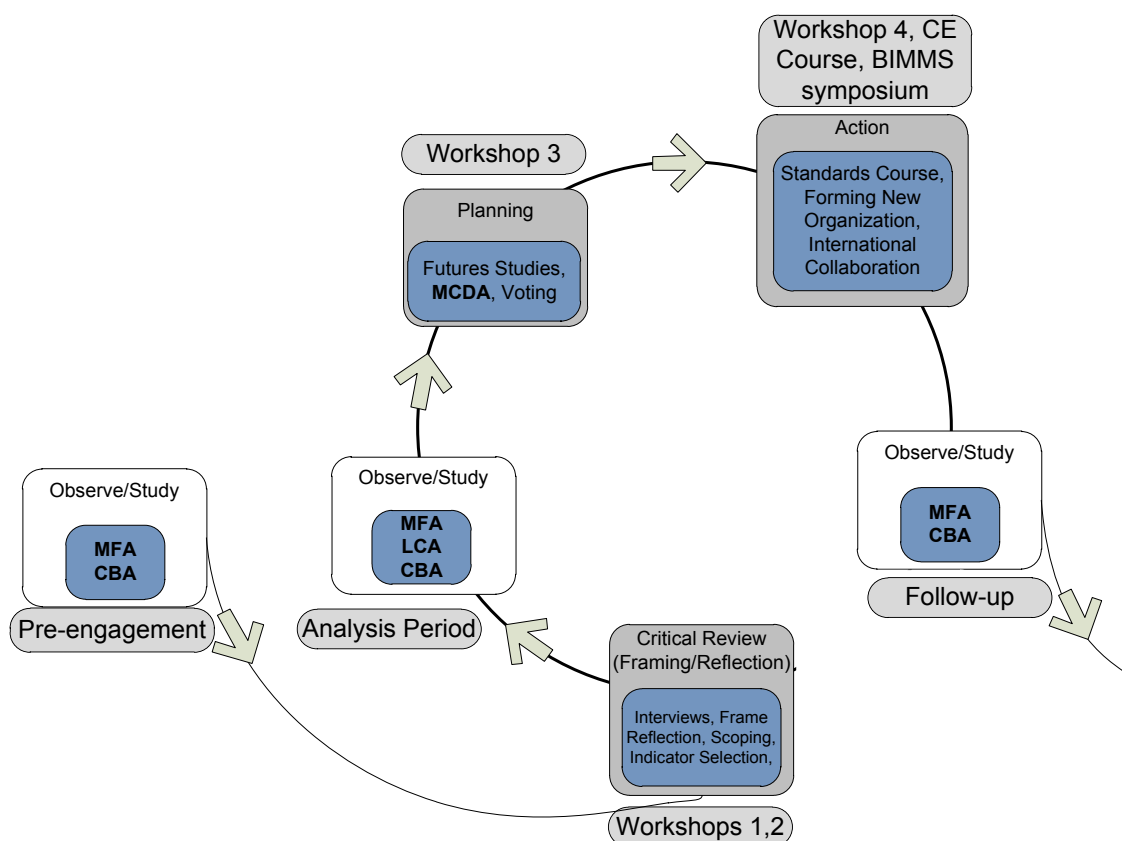


Figure 9 - The use of various methods in the BRA (C&D) Project where systemic analysis tools from industrial ecology are in bold

Pre-engagement

Previous to the engagement process which began in 2009, material flows accounting (MFA), cost benefit analysis (CBA), and stakeholder interviews were performed (Aid 2008). The use of these tools is illustrated in Figure 9 on the bottom right pre-engagement step. These results from analyses were later used as background information during the initial phases of the project (Workshops 1 and 2 in Figure 9). The results of this phase and following stages are presented in Section 3 – Results.

Workshops 1 and 2

The first workshop was structured to perform a systems framing and broad reflection of the current state of the system. To achieve this, rich pictures (Checkland 1999) and focus groups (Morgan 1996) were employed.

The second workshop aimed to refine areas of focus and select indicators for furthering the understanding of the current system state. Methods used here were convergent interviews, voting, and focus groups.

Analysis Period

After the selection of priority areas and relevant indicators, rough MFA, LCA and CBA were performed with data from the participating stakeholders and public data. See Papers I and II for more on the application of these methods.

Workshop III

This workshop was arranged for the review of the current situation as measured by the indicators and for planning the collective actions to be performed to improve the system.

Here, focus groups were once again used, this time to compare reality to the indicators and study results. Other methods employed were vision building, multi criteria decision analysis (MCDA), voting, and specific action planning.

Workshop 4 and BIMMS

This final stakeholder workshop and symposium was organized for the most part to follow through on the action plans created in workshop 3. First, critical review was employed to reflect on the project actions and analyses. Focus groups were then utilized for planning a new branch organization, and strength and weakness assessment was performed to evaluate the potential modes of such a branch organization.

3.1.3 The use of the individual mixed method engagement cycles of project BRA

In the previous section, the view of the BRA project through its macro action research cycle was explained. These action research cycles may be implemented on smaller scales as well. For example, the various engagement phases of the project were structured as separate action research cycles, with each subsequent cycle beginning by reflecting on the previous engagement phase. This is shown in Figure 10.

Figure 10 and Figure 11 show the micro progression of the project whereas Figure 9 shows the macro (broader) progression. Within these cycles it was often industrial ecology tools such as LCA, MFA, or CBA that were employed for studying areas of priority and relevant indicators. To see more of these processes throughout the project see Papers I and II.

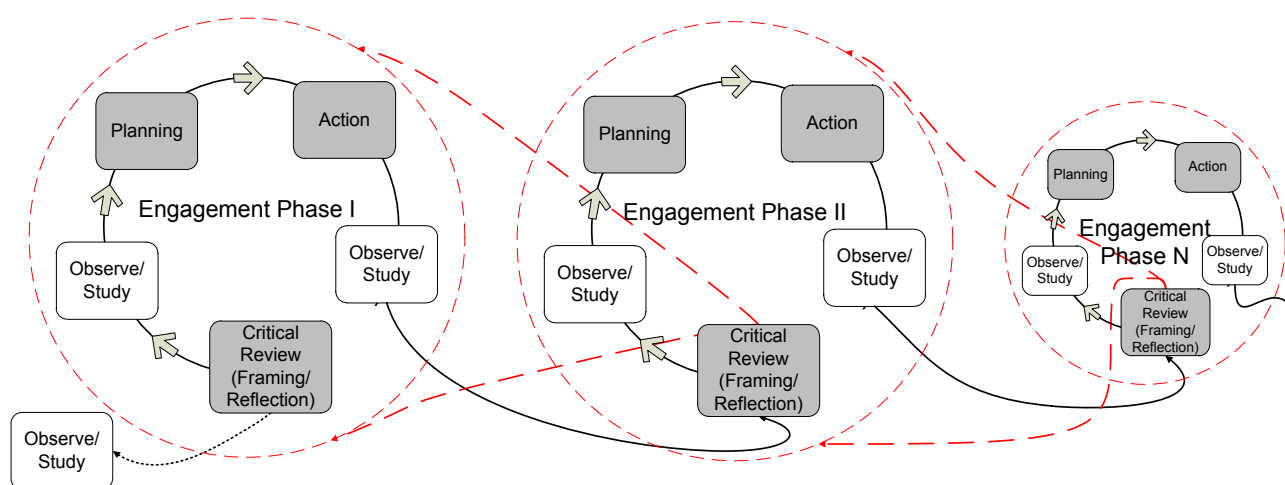


Figure 10 - The 'Micro'progression of individual engagement phases and their reflective actions focused on previous phases' activities. Reflection is shown in red dotted lines.

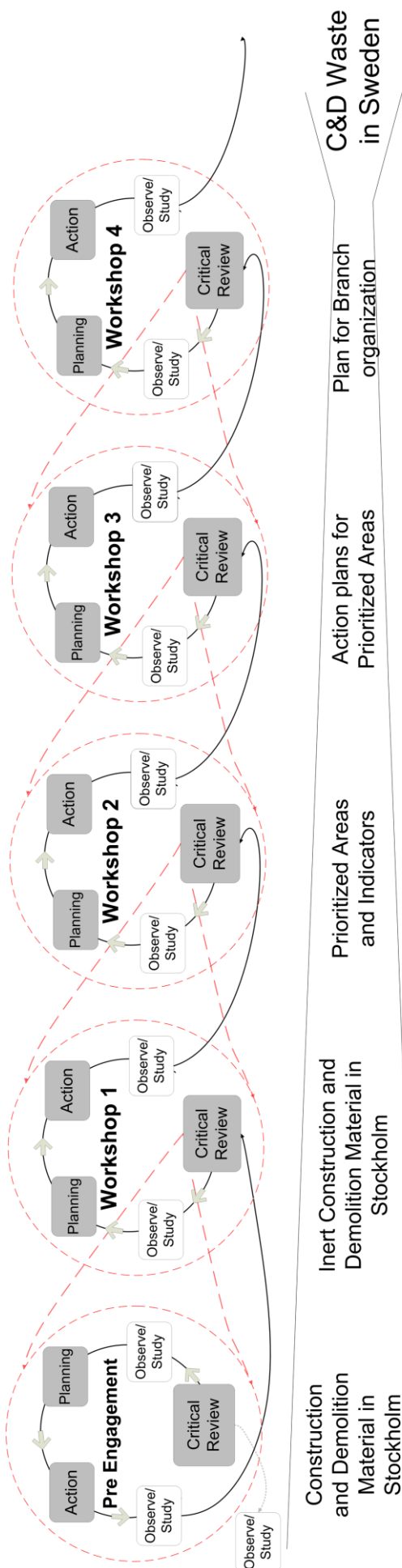


Figure 11 - The process of focusing-in throughout the project - and eventual widening after addressing identified issues.

Red dotted lines in *Figure 10* and *Figure 11* represent the act of reflection/review projected backward. It is in this step that previous reflection, studies (often utilizing industrial ecology tools), planning, and actions are reviewed for their effect and efficiency in regards to wide project aims and process objectives. In the beginning of the project, we attempted to institute a full 'ladder of reflection' in each of the reflection steps (see Section 2.5 for more on the ladder of reflection and its steps). However, this very encompassing reflection process blurred the direction of the project and its micro aims. Therefore, employing a full ladder of reflection less frequently was seen as more appropriate.

In project BRA, a broad framing and reflection was performed during the first workshop. Later on more delimited reflection focusing on study results, methods, and policy was employed on a relatively frequent basis. Reflection on wider contextual and macro issues was kept to a minimum.

This approach allowed for the use of the action research procedure to slowly focus in on areas of importance and explore more in depth areas of tightening scope with the help of industrial ecology methods. This process of focusing in (as introduced in *Figure 4*) during the BRA research project is illustrated in *Figure 11*. The issues of salience became more pronounced as the project progressed. A good time for employing a full 'ladder of reflection' (*Figure 7*) might be as the project enters its next life as a branch organization (shown on the right of *Figure 11*). Here a reassessment and reflection on actors, areas of priority, contextual systems, and issues of concern could be more appropriate.

3.2 The Looplocal Case – Paper III

3.2.1 Background to the method

Industrial symbiosis (IS) developments have generally been differentiated as ‘self organized’, ‘facilitated’, and ‘planned’ (Paquin and Howard-Grenville 2012). This project looked to introduce a tool – “Looplocal” with objectives to support the strategic facilitation of IS. More specifically, ‘Looplocal’ is a visualization tool developed to assist in 1) the identification of regions prone to new industrial symbiosis activities 2) market potential exchanges to key actors, and 3) highlighting for aspiring facilitators the various strategies and social methodologies available for the initial phases of a facilitated industrial symbiosis venture. On a national or regional scale, the tool aims to give a quick overview of what could be the most interesting regions to prioritize resources for IS facilitation. Focusing in on a regional level, the tool looks to visualize the potential structure of the network in that region (centralized, decentralized, or distributed), allowing a facilitator to adapt the networking approach correspondingly. The tool can also visualize potential IS transfer information, along with key stakeholder data. A proof of concept run of this tool was performed in the ‘industrial disperse’ context of Sweden (See Paper III). In its early stages of application, the method has proven capable of identifying regions prone to the investment of facilitators’ resources. The material focus and custom possibilities for the tool show potential for a wide spectrum of potential facilitators: from waste management companies (using the tool as a strategic market analysis tool) to national or regional authorities looking to lower negative environmental impacts, to ‘sustainable’ industry sectors looking to strengthen market positioning.

3.2.2 The method

As explained in more detail in Paper III, Looplocal was first conceptualized and developed by the author and colleagues at the 2011 Stockholm Green Hack-A-Thon as an ICT tool for resource management. Looplocal is a heuristic data analysis method which combines waste statistics, life cycle inventory (LCI) data, and national industrial data to perform heuristic analyses of raw material and energy inputs and outputs (wastes). For details of this methodology see Paper III. The tool performs and visualizes heuristic regional output to input ‘matching’ with a list of ‘waste to raw material’ substitutions (which may be direct, combined, or upgraded) gathered from IS uncovering studies¹, IS organizations, and waste and energy professionals. On a national or regional scale, Looplocal aims to give a quick overview of what could be

¹ An ‘uncovering’ study is one in which industrial symbiosis networks are sought out in existing business relations. See Baas (2011) for an example.

the most interesting regions to prioritize resources for IS facilitation. On a regional level, the tool looks to present the potential symbiosis structure of the network in that region, thus allowing a facilitator to adapt their facilitation approach correspondingly.

3.2.3 The procedural use of Looplocal method in engagement processes

Looplocal was never intended to be used in a vacuum, and was designed specifically as a support tool to be embedded within larger stakeholder engagement processes. In contrast to the predominantly post-engagement use of industrial ecology's analytical tools in project BRA, Looplocal uses these tools principally previous to stakeholder engagement processes. While there are interesting uses of Looplocal after engagement has taken place (See Paper III, Section 4.5), this section will focus on the methodology pertaining to the initial strategic uses of the Looplocal.

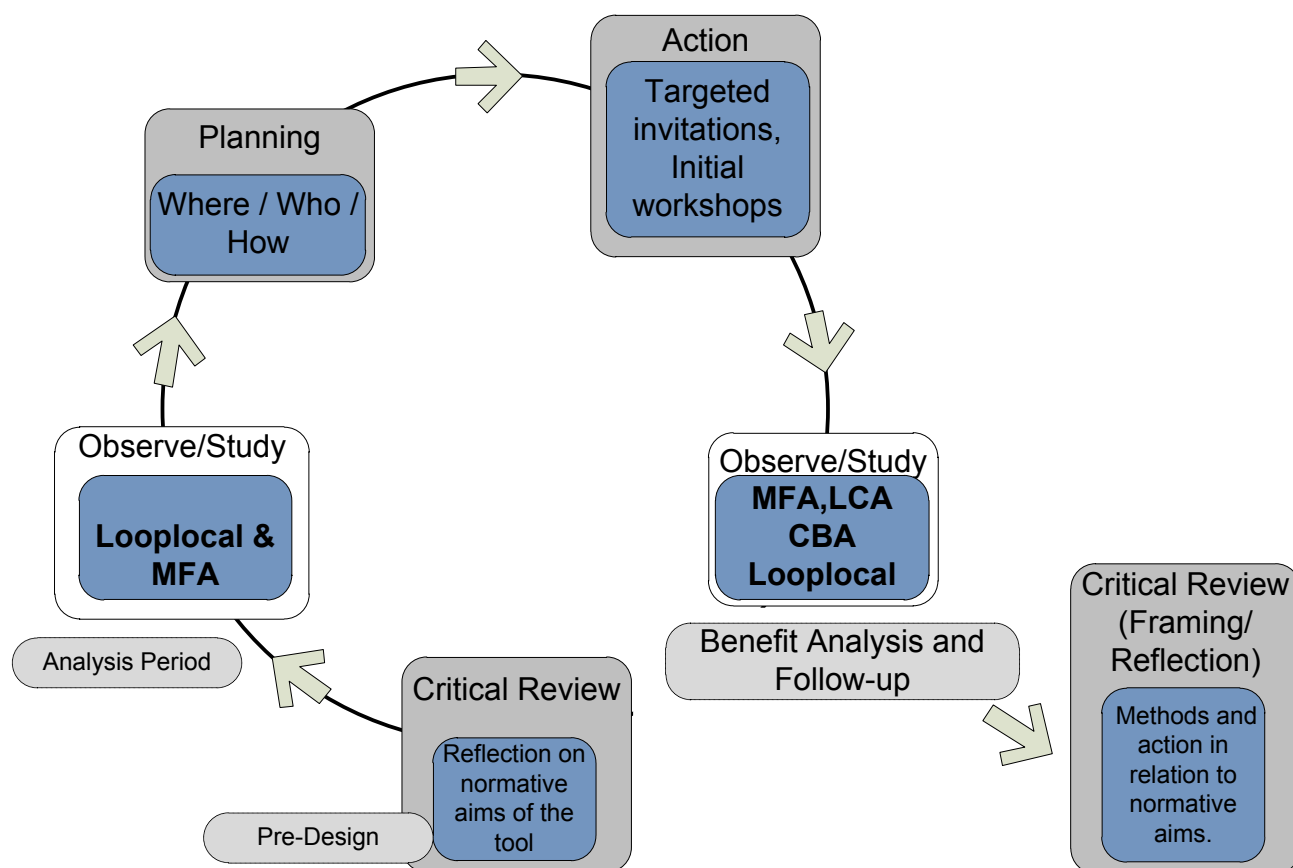


Figure 12 – An action research cycle illustrating the strategic macro application of Looplocal in an engagement process

As shown in Figure 12 Looplocal is intended to be employed strategically after the normative aims of the tool have been identified. On a national level these normative aims could steer the process toward finding the regions that present the largest potential for reductions in total resource use, greenhouse gas emissions, hazardous waste production, transport distances, fossil fuel use, or other factors. The tool could

also be weighted to identify the most economically viable symbiosis opportunities. Similarly, on a regional level the normative aims selected in the initial framing could be guides in regional selection and identification criteria.

After the process is run with targets set in accordance to the normative aims, suggestions for regions, stakeholders within the regions (and their respective material and energy flows of interest) can be used to plan the facilitative engagement work. Strategic plans may include what regions to place resources on, what actors to approach, and how to approach them. For more on these tactics see Paper III.

Other tools from the industrial ecologist toolbox may be employed after the initial engagement workshops or focus groups to confirm the heuristic projections of potentials identified in the analysis and interaction phases. These tools might also be used to further analyze potential for other systems improvements (according to stakeholder perceptions of salience). In further action research cycles, industrial ecology tools such as LCA, MFA, or CBA could be utilized to audit the outcomes of resulting new symbiosis connections.

4 RESULTS

4.1 Case I: The Construction and Demolition Material Project (BRA)

It can be challenging to lineally delimit the results from the methods in iterative processes such as those used in the BRA project. Often the results end up refining and leading to the next round of methods which lead to results and a refining of the methods and the next line of methods - and so on. I have taken the periods described in Figure 9 and Figure 10 to structure the presentation of results.

4.1.1 Pre-Engagement Period

The pre-engagement analysis posed, among other things, that the C&D waste in the Stockholm region was dominated by non-metallic inert fractions (around 40% of the mixed waste streams and up to 70% of the sorted waste streams)(Aid 2008). This was reinforced by the Swedish EPA's national waste statistics showing 6.5 of 8.2 million tons of nonhazardous C&D waste (mixed and source sorted) as being mineral fractions (Swedish EPA 2008). The information from these MFA's and CBA's (from Aid 2008) were utilized as initiation points in the interviews of 2009 and the first two workshops (See Figure 9). While the mineral/inert fractions dominated the C&D waste streams, the economic potential of the organic streams seemed even higher. The wood, paper, and plastic fractions could be upgraded for various new uses, such as oils for a nearby asphalt plant or as fuels for vehicles or other waste management processes. The economic potentials of such options were roughly analyzed using CBA in Aid (2008). During the first workshop, stakeholders were gathered to refine project aims and goals, select materials of interest, refine the system of focus, identify other stakeholders of importance, and set areas of priority focus (See Paper I).

4.1.2 Workshop 1

The initial workshop aimed to focus the projects aim, system borders, stakeholders, and methods forward. Previous methods of MFA and CBA, and interviews were reflected upon and new methods of focus groups, rich pictures and voting were employed.

Results of the rich pictures

Focus groups in the first workshop were given sheets of paper to collectively illustrate the system with which they foresaw us collaborating to improve (its actors, material and information flows, issues, driving forces etc). The three images they produced were all quite different, and the act of discussing and describing these images helped the group as a whole to better understand what system we were working with and its up and down stream effects. The image was intentionally left messy and unstructured to allow for unexpected ideas and critical thinking, as opposed to spending too much time of classifying and reducing the whole to its parts. A synthesis of the three rich pictures from Workshop 1 is presented in Figure 13.

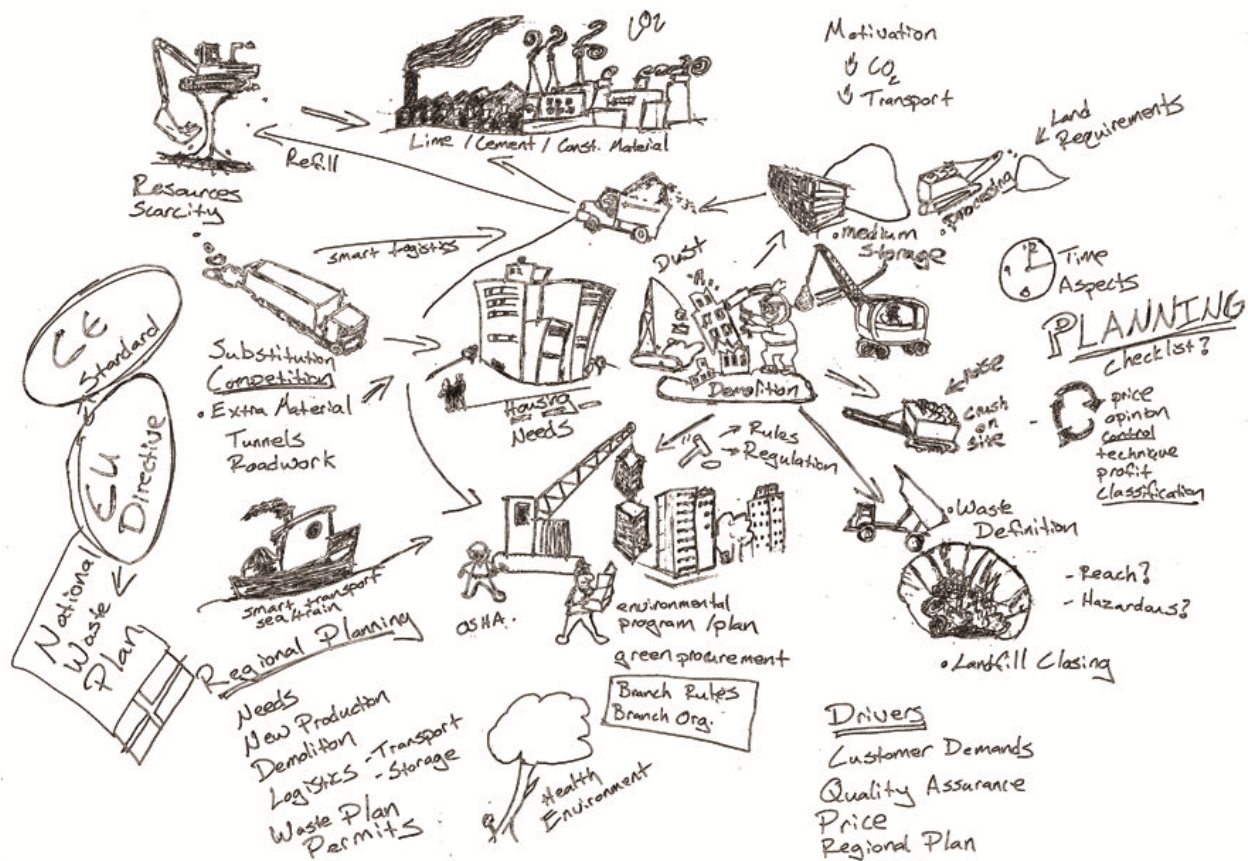


Figure 13- A compiled rich picture from the various participants at the first BRA workshop. The image was left unstructured to place a heavier focus on relational idea generation than that of reductionist classification.

Results of the focus groups and voting of workshop 1

According to the information from the MFAs and CBAs in the initial phase as well as from the literature review, interviews, and in workshop rich pictures a focus was placed on the non-metallic inert fraction in the first workshop. A general aim was set to improve the sustainability of the newly identified system through focusing on *optimizing the mass flows of inorganic materials*. General priority areas to focus on and improve were identified as *environment, economics, collaboration, product (quality, classification, and technical), and statistics* were selected by the group in this workshop.

4.1.3 Workshop 2

With additional stakeholders in attendance and holding the priority areas (identified in workshop 1) in consideration, a list of indicators was produced during Workshop 2. These indicators would later be measured during the analysis period in Figure 9, and discussed in the planning phase of Workshop 3, and acted upon in the following phases. The resulting indicators (and their initial measurements using MFA, CBA, and literature review) in areas of climate, resource use, market economy, and product quality are shown in Table 2.

Table 2- Indicators selected and used in the BRA (C&D) project. The indicators' measured values, methods of measurement, desired values, and respective action plans

Prioritized Area	Indicator	Measured Value	Method & Indicator Reliability	Desired Value	Action
Climate Impact (Environment) and Transport	km/ton waste	23km	Company Statistics, MFA <i>High</i>	<15km	Planning for onsite reuse and regional temporary storage sites with municipalities
Climate Impact (Environment) and Transport	Ton waste / truck	6.6ton	Company Statistics /MFA <i>Medium</i>	Ca. 25-30	Planning for centralized logistics at C&D sites
Climate Impact (Environment)	C02 eq. Exhaust per ton	* ¹	Screening LCA, Literature Review <i>Medium</i>	Down – need more statistics	Work on Statistics, Possible collaborative green marketing action of branch organization
Resource Use	Sorting grade (% sorted of total weight)	75-85 on large projects	MFA/Company Statistics <i>High</i>	>90 lg. projects >70 sm. projects	Company targets, collaboration with sorting entrepreneurs
Resource Use	Waste Effect (kg waste leaving the region / gross building area of the project)	20-50kg /m2 construction, 200-500kg/m2 demolition	Survey, Company Statistics, Literature Review <i>Low</i>	<20kg/m2 construction, <200kg/m2 demolition	Coordinated planning for reuse on site or nearby, The use of centralized logistic hubs, crushing on site
Markets / Economy	Price of Low grade fill 0-30	30SEK	Market Survey <i>Very High</i>	90-100% of virgin price	CE Certification, GHG calculations, lobbying for customer demand
Markets / Economy	Price of Clean recyclable 0-63	60SEK	Market Survey <i>Very High</i>	90-100% of virgin price	CE Certification, GHG calculations, lobbying for customer demand
Markets / Economy	Price of Crushed Asphalt 0-16	70SEK	Market Survey <i>Very High</i>	90-100% of virgin price	CE Certification, GHG calculations, lobbying for customer demand
Product Quality	Wide understanding and application of material standards	Low use of CEN/CE standards for recycled materials	Survey of delegates, Interviews <i>High</i>	High use of CE standards for recycled materials	Organized course in October 2012, Communication with EU branch “FIR Recycling”

*¹ Very dependent on transportation distances see (Blengini and Garbarino 2010)

4.1.4 Workshop 3

The results of the analysis performed between the second and third workshops (utilizing public as well as non-public participating company data) on the indicators were presented in the third workshop. Focus groups were then formed to compare the stakeholder's knowledge of the real system to the measured indicators. All indicators, except that of the waste per gross area seemed to be relatively realistic according to the stakeholders. A suggestion to divide the indicator for *waste per gross area* into new construction, renovations, and demolition, respectively, was made. During a planning focus group a goal was set to imagine desired or more ideal future situations for the system at hand and the aim identified in Workshop 1: From these scenarios, plausible levels for the indicators were discussed. It was difficult to set levels on each indicator but some rough suggestions were given for each. These desired values are presented in the "desired value" column of Table 2.

From the scenarios discussion, the indicator gaps, and reflection on previous stages a rough list of group actions was established and prioritized through a voting process. A focus was set on creating more demand for recycled aggregates.

Some of these actions were:

1. To stimulate recycled aggregate demand it was suggested that a marketing campaign aimed at the users of aggregate materials, contractors, and housing agencies, etc. would be beneficial. This would include: education of the above mentioned actors in the quality of recycled materials, the availability of such materials, the environmental benefits of using the respective recycled materials, other benefits (economic, goodwill), guidance on how to go about requesting and using such recycled products, etc.
2. Establish stricter quality controls of the materials (included in CEN standards)
3. Lobby for higher requirements for the use of such materials in the "Swedish Waste Plan"
4. Establish an online market for materials (that works better than the one in existence)
5. Place a higher tax on virgin materials
6. Raise Land filling costs
7. Set restrictions on using clean, easily recyclable material (such as clean concrete) as landfill cover.
8. Work with the planning office and local authorities to set up "medium sorting and storage" near to strategic locations (such as large construction regions or renovation projects).
9. Find or build an organization to represent Sweden in the European construction and demolition lobby (FIR).

As can be seen, many of these actions are outside the hands of a single stakeholder or indeed the stakeholder group as it currently stood.

Point 2 was later addressed in the autumn of 2011 as a course organized by the author together with The Cement and Concrete Institute and the Swedish Mineral Processing Research Association (Föreningen Mineralteknisk Forskning). Several of the project stakeholders enrolled to increase their grasp of CE marking and European regulations for recycled materials.

It was also agreed by delegates that points 1-8 would best be approached as a singular body. It was in Workshop 3 that the idea for an industry interest group should be formed to lobby, inform, market, and coordinate further actions regarding such materials in Sweden (the focus was widened to a national scale). After the third workshop in regards to a questionnaire focused on analyzing the usefulness of these tools, most stakeholders noted their improved grasp of the problems at hand and the supply chain effects of various materials (see Paper II).

4.1.5 Workshop 4 – BIMMS Symposium

An international symposium, Baltic Inert Material Management Symposium (BIMMS), was co-organized with the Sustainable and Innovative Material Management for Construction in Cities (SIMM-CCities) initiative. During this symposium the Swedish delegates laid groundwork for the establishment of a Swedish C&D recycling branch organization. Before the symposium several of the stakeholders were interviewed and a suggested framework for a branch organization was formulated. This framework included the i) the construction and demolition companies and ii) the recycling companies as core members, while the estate management, consultants and transport companies also held board representation roles. Areas of communication, education, collaboration planning, lobbying, research, and statistics were suggested as main activities to be coordinated by a single branch employee.

In the fourth workshop within the BIMMS conference the issues of governmental contact, standardizing and quality control, and education were collectively selected as the areas of priority for the future organization. Focus groups evaluated the strengths and weaknesses of various potential formations of the future branch organization. The various stakeholders agreed to continue the initiative and reconvene later in 2012. This initiative was a vehicle for continued collaboration on the priority action areas and requirements identified in the BRA project. The stakeholders taking ownership of the AR process could be seen as positive in regards to the normative aims of the research and the need for further cycles of evaluation, planning, and action. In Paper II the stakeholders' sentiment of the success of the project in regards to stated aims was shown as positive (assessed through post workshop and post symposium questionnaires).

4.2 Case II: Looplocal

As detailed in Paper III, the heuristic data analysis tool, Looplocal, resulted in output believed (by the recycling industry and consulted academics) to be beneficial for strategically facilitating new industrial symbiosis networks in industrially disperse regions. Together with the co-authors of Paper III, a proof of concept run of this tool with Swedish statistics was run. In its early stages of application, the method has shown potential for identifying regions thought to be conducive to the investment of facilitators' resources along with lists of attractive potentials in these regions. While Looplocal is explicitly a 'strategic' tool, it is possible to involve varying levels of normativity through adjusting the approaches and applications of the tool.

Some results of the method (including its symbiosis matching) detailed in Figure 1 of Paper III are summarized in Table 4 below. The top 10 municipalities (by number of potential synergies) are shown in Table 4. By dividing the number of potential synergies by the number of industries (NACE¹ A-F) included per municipality, it is shown that the number of 'potential synergies per organization' in this list range from 2.7 up to 10. It is also shown that the regions with most industries are not necessarily the regions with the most IS potential (according to the synergies included).

Table 3 - The top 10 municipalities prone to symbiosis facilitation as identified by the Looplocal tool's assessment of number of potential synergies

Municipality	Number of potential synergies identified	Total number of organizations included in the dataset analyzed	Average number of synergies per organization modeled
Stockholm	5999	653	9.2
Helsingborg	3632	362	10.0
Göteborg	2967	584	5.1
Norrköping	2519	317	7.9
Eskilstuna	1736	285	6.1
Hässleholm	1404	224	6.3
Värnamo	988	219	4.5
Jönköping	963	348	2.8
Västervik	906	201	4.5
Karlshamn	858	152	5.6

¹ NACE (Nomenclature statistique des activités économiques dans la Communauté européenne) is a European industry standard classification system consisting of a 6 digit code.

All intra-municipal connections output on the first run were mapped in a Google heat map as shown in Figure 14. This is an example of how Objective 1 of the Looplocal tool (the identification of regions prone to new industrial symbiosis activities in a nation) could be visualized on a macro scale.

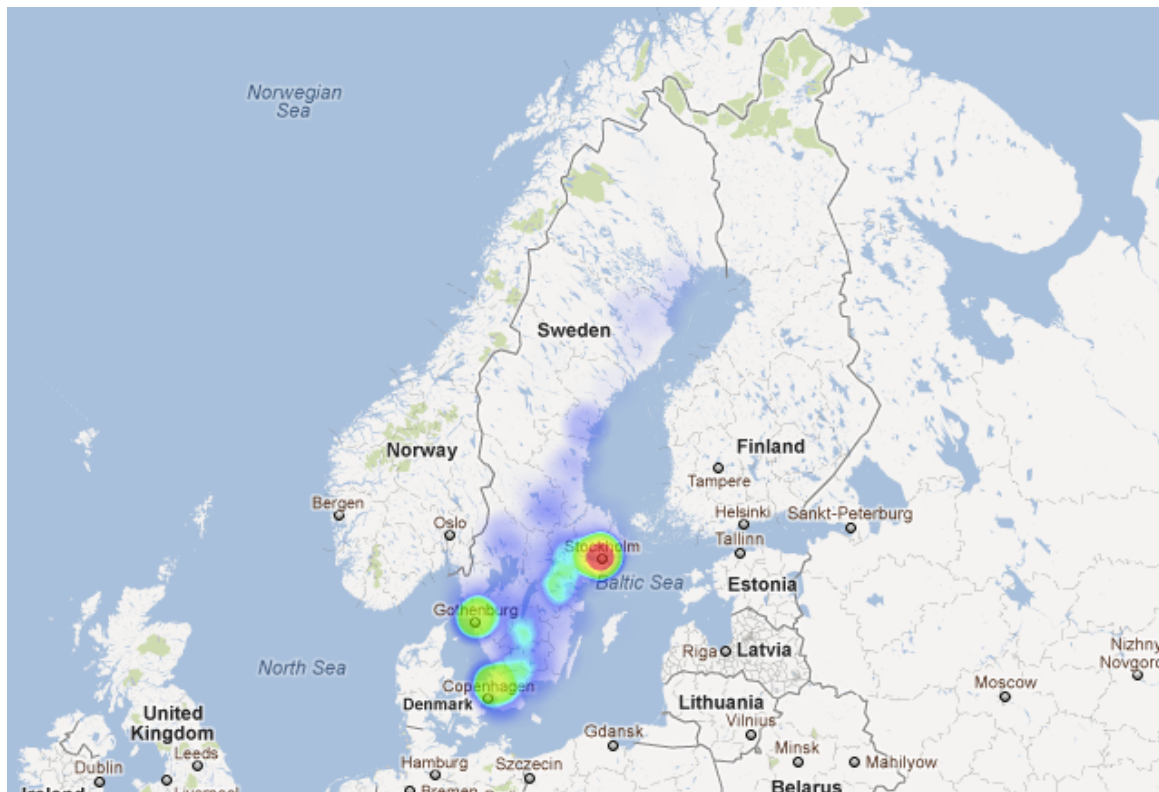


Figure 14 - Heat mapped intra-municipal potential synergies connected in Looplocal

Another way to summarize some of the main results from the intra-municipal matching is to look at the most common material connections. As shown in Table 4, substituting fossil fuels, fertilizers, lime, and plastics hold some of the greatest potential in Sweden.

Table 4 - Some of the top potential material synergies identified through the Looplocal tool.

Substituted material	Number of potential synergies (national intra-municipal)
Hard coal	10270
NPK fertilizer	2507
Peat	2322
Wood	2120
Steel scrap	1510
Plastics	933
Brick	601
Bark	445
Wood Packing	445
CaCO ₃	287
Iron	268

5 DISCUSSION

Just as there are many interesting approaches a researcher could take to toward analyzing and working with resource management, so are there many interesting ways to discuss these cases. First, I address and discuss directly the results of the cases and the use of the pragmatic research approach developed in response to Objective A. Thereafter, I have structured my discussion around the themes of *normativity* and *assumptions*. I have taken this as a forum to further address objectives C, D, and F. Additionally this discussion reflects back on the guiding ideals of the thesis, and discusses the embedded nature of industrial ecology tools and their meaning in general for approaching the normative, macro, aim of dealing with resource (mis)management.

5.1 Discussion of the Case Results

5.1.1 Case 1 – Discussing the process and results of the C&D project

In presenting the results, I demonstrated the pragmatic combination of action research and industrial ecology analysis methods to work toward improved cycles of C&D materials in the Stockholm region. The reasoning for such a participative and mixed-methods approach stemmed from the reasoning that:

- When there are subjective perceptions of improvements in relation to the sustainability of a system of focus;
- and that the research goals of a project include improving the sustainability of said system of focus;
- then it should be reasonable and beneficial to utilize and promote rigorous methods to account for, learn from, negotiate between, and inform the involved actors/interests.

In the final stages of this project, several of the participating stakeholders decided to take what they had uncovered and learned and use it as the base of a new cross-sector association and cluster. This was the beginning of new cycles of action, reflection, and planning in priority areas clarified within the project.

Did this multi-method AR process provide a positive result? If the main aim of the researchers was to engage stakeholders around an issue and promote multi-perspective improvements it could be considered a success. However, the amount of time and other resources invested in planning, organizing, communicating within, and performing such a multi-partner project can easily become more intensive than that of more focused mono-method approaches. Each workshop required 100 or more hours for preparation and an additional 100 or more hours of collective work on the day of the workshop. The symposium took well over 200 hours of planning time and ca 800

hours of collective efforts during the two day event. These engagement tasks could distract researchers from their research tasks of structuring and communicating such proceedings.

The semi-structured approach to collectively defining the system and prioritizing problem areas allowed for key issues (such as the pressing need for collective planning and regional medium term storage of construction aggregates) to arise in the BRA project. These and other issues may have been difficult to recognize if a pre-determined analysis methodology had been taken from the beginning. The process also allowed for the issues and problems that were important to key stakeholders to be focused upon. In accordance to Objective D, These show some of the strengths of such a bottom up and mixed method approach.

However, the use of the AR procedure may have led to a less quantitative enterprise than if another research procedure had been chose. Additionally, to the author, the AR procedure may slant such work toward a more facilitative or even consultancy styled project than traditional post-positivist academic research may be comfortable with. In the end the normative aims of the project took priority over the descriptive objectives, and the effects of such have not (and in entirety could not have) been analyzed.

5.1.2 Case 2 – Discussing the process and results of the Looplocal strategic tool

In regards to investigating the potential for strategically supporting the facilitation of resource efficiency with an ICT (Objective E), many interesting potentials were shown by the Looplocal tool. It was not intended that all 6,000 of the identified potentials be followed up individually – only that areas of higher IS conductivity be highlighted and potentials drawn out as to increase the effect of facilitation practices. In time and given proper resources, the correlation between Looplocal hot spot results to success indicators over several intervention regions, along with other aspects such as the “Short mental distance” discussed by Ashton and Bain (2012), would be a good next step.

Interestingly, the results in Table 3 (and Table 1 of Paper 3) show some less-dense industrial regions as having higher IS potential than other more-dense industrial regions (such as Helsingborg and Göteborg with 362 and 584 organizations respectively and symbiosis potentials of 3632 and 2967 respectively). This result contrasts the alternative identification strategy of simply using industrial density metrics. This can be a premature result as the amount of processes (LCI datasets) included and the number of symbiosis potentials is still relatively low. The number of potential instances in a region will be highly correlated (but not entirely) to the amount of industries in the region that are represented in the databases.

Looking at Table 4, fuels to be substituted such as coal, peat, bark and wood are dominant. There is currently strong competition in the Swedish market to enable the use of lower grade secondary materials for use as fuel in industry. As materials such as paper, packaging and clean wood are increasingly used for material recycling or high grade liquid fuel production; lower grade secondary materials such as mixed residues and process sludge and becoming more interesting for replacing expensive and climate impacting fossil fuels.

In addition to fuels, sources of fertilizer are also high in Table 4. This can be partially attributed to the number of farms as well as the number of organic waste producing facilities (such as pulp and paper industries) included in the datasets.

These two dominant areas of fuel and fertilizer elicit a few reflection points for aspiring facilitators in Sweden.

- 1) These could be good areas to focus efforts for creating new resource networks and consortia.
- 2) Additional weighting techniques in the model would be beneficial to highlight for example: flows with greater economic significance, flows with higher environmental impact, large flows, flows with more ‘transferability’ across systems, etc.

5.2 Discussion over the pragmatic, mixed method, approach to the cases

5.2.1 Strengths of the pragmatic approach

As put forward by Greene et al. (1989), there are five major rationales for conducting mixed methods research. These are 1) triangulation (i.e. strengthening results through the convergent results of different methods), 2) complementarity (i.e. the clarification or elaboration of the results of one method with the use of another), 3) initiation ,such as Schön and Reins (1995) term ‘framing the situation’, 4) development (i.e. using the findings from one method to inform another), and 5) expansion (i.e. seeking to expand the scope of a method or a project through the use of different inquiry tools).

Sometimes the addition of a method from another paradigm, such as rich pictures to a post-positivist study, can fulfill several of these strengthening rationales. For example, the rich picture, Figure 13, in the author’s C&D case provided the groundwork for ‘initiation’ in the system definition, basis for the MFA study, as well as the ability to expand the scope of the interview method.

5.2.2 Weaknesses and pressing questions of the pragmatic approach

The use of pragmatic approaches in the sustainability field can also elicit many pertinent questions. Questions such as those brought up by, among others, Fien (2002), Johnson and Onwuegbuzie (2004), and Mertens (2003):

- What criteria can be used to judge whether a research topic is worthwhile? Are there ways of peer reviewing our ‘sustainability’ research topics and questions?
- How do we judge the appropriateness of particular data collecting and analysis techniques?
- Who owns the data we gather, and who has the right to use the findings of ‘our’ normative research?
- For whom is a pragmatic solution useful?
- Is the traditional linear relationship between research, dissemination and adoption appropriate, particularly in pressing ‘sustainability’ situations?
- How should the uncertainty of any research conclusion be factored into participative policy oriented projects?
- How could a researcher prevent invested parties from ‘hijacking’ participative research projects?

There is much left to develop with such approaches, as put succinctly by Johnson and Onwuegbuzie (2004 pg. 15) “*Much work remains to be undertaken in the area of mixed methods research regarding its philosophical positions, designs, data analysis, validity strategies, mixing and integration procedures, and rationales, among other things.*” There are also capacity (resource and knowledge) issues at stake. Concerns may arise as to the requirement for the researcher to understand and perform properly methods from several fields. Also problems may arise with the cost and time requirements of using more (mixed) methods.

While questions and concerns such as these can be daunting for those choosing to employ multi-method approaches; I believe the community of sustainability researchers and practitioners is up to the task of confronting them.

5.3 The embedded nature of analytic methods in normative processes

Even when not embedded within *explicitly* normative processes¹, analytic methods (such as LCA, MFA, Looplocal) can be embedded in highly normative processes. One might even argue that all analytic methods, however objective in themselves, are placed within normative processes. Ontological and epistemological processes such as: acknowledging what can be studied, deciding macro areas of focus, defining the

¹ Explicitly embedded analytical tools in a normative process could be exemplified by Figure 6.

problem situation, selecting substitute or comparative systems, setting the system boundaries, and selecting the methods to be employed, to some degree implicitly hold notions of ‘what ought to be’ – notions of normativity.

This may be more pronounced in heavily human influenced sciences such as social or economic studies. However, I believe normative aspects do exist even in the more ‘pure’ basic research arenas. Basic research, as opposed to applied research, has a main objective of simply expanding human knowledge. However, the spin off effects of this knowledge, ethically, should not be entirely overlooked by the researcher. While the causality may not always be crystal clear in every case, basic research often lays the foundation for applied research and what ‘will be’ or ‘might be’ in the future. In the next section, the meaning of assumption reflection is examined, furthering this concept the two case studies and their assumptions are then reflected upon.

5.4 Beyond Transparency – Assumption Reflection

Formulating the fundamental approaches to normative ventures, often embedded in the beginning of a study, may range from more individual to more collective processes.¹ Correspondingly, the fundamental assumptions and resulting normative aspects of studies - and processes therein - may be acknowledged inwardly and outwardly by the individual or group to varying degrees. Explicitly communicating a venture’s normative aspects, along with methods, procedural methodologies, and sources could be considered a major part of external transparency. However, such transparency does not ensure that we are being entirely transparent inwardly (to our core project group and to ourselves). Below, an inward reflection over the assumptions of the BRA project and the Looplocal project is attempted, in hopes to expand both inward and outward transparency.

5.4.1 Some assumptions of the BRA project

Below (in no particular order) are some of the author’s and project participants’ key assumptions that lay behind the BRA (C&D) project’s process formulation, approach, method choices, scoping, etc.

- The flow of C&D materials in Sweden is unsustainable under a resource use perspective.
- It is possible to delimit and study the sustainable improvement of such a ‘system’ to an extent.
- Mechanisms exist across multiple actors that structure the C&D system as it is today.

¹ If one subscribes to social constructivist theory, these processes would be to a largely collectively steered.

- Changes in these network mechanisms are required for substantial movements toward sustainability.
- Engaging stakeholders from relevant areas of the system will enable bottom up change of system mechanisms given sufficient momentum is generated.
- Sufficient momentum can be created in the engagement processes to create change.
- A group of representative stakeholders can be assembled and their new multi-perspective aims of sustainability will be compatible with the broader normative aims of the project.
- Co-created plans will be more actionable than externally imposed improvement plans.
- Knowledge expansion regarding the system will motivate stakeholders to take rational collaborative action toward improvements (rationality).
- Recycling is inherently good.

By no means were all of these assumptions correct for the working context of the project. Does this mean the project was a failure? This again, depends on our larger (normative) aims. In Paper II the stakeholders' sentiment of the success of the project in regards to stated aims was shown as positive (assessed through questionnaires). In this thesis, we do not reenter a discussion evaluating the level of success or failure as such. Instead, below I have reflected and looked more closely into a few of the above assumptions, and questions that stem from these assumptions.

The assumption that bottom up engagement will catalyze change

There is a substantial body of research that stands behind the notions of multi-stakeholder engagement for change (Reason and Bradbury 2007). Indeed the engagement process feels more democratic to many of us. There is also a great deal of modern economic and social theory that is based on the concept of rational humans acting in accordance to vested personal interests (often exemplified by homo-economicus - the neoclassical economic human)(Wolff and Resnick 2012). These two assumptions of the 'efficacy of engagement' and the 'ability of actors to rationalize and adjust their actions according to new information' led to the process design as shown in Figure 6. Much of the reasoning behind the selection of this approach is grounded on these assumptions. Does this mean that if a certain change seems logical (personally and collectively) after a collective investigation that the rational change will come about? If not, does this signify a lacking capability in analysis results, or the communication thereof? Perhaps such a lack of action would signify incompatible perceptions of sustainability or signify an ineffective or incomplete engagement

process. While outside the scope of this thesis, there are many questions behind the assumptions of rationality and the efficacy of engagement (in contrast to other change strategies) that would be interesting for further research.

The assumption that recycling is inherently good

The thought that recycling is inherently good has been engrained, or conventionalized, in our societal thinking of material flows. The validity of this statement depends on what is normatively seen as good. Is it the reduction of greenhouse gas emissions (above ecosystem uptake levels) from transport that is seen as good? Is it the reduction or elimination of the use of materials mined from the geo-sphere that is seen as good? Is it the act of keeping materials circulating within our economic systems for as long as possible that is seen as good? Is it the act of limiting the entropy and dissemination of hazardous (and substances of unknown hazardous properties) that is seen as good? These various conceptions of what is good in relation to materials in our society do not always align with each other, and indeed may lead to contrasting conclusions of what to do in regards to material management.

An underlying assumption that cycling C&D materials was good supported the initial broad goal of ‘improving the cycles of C&D materials in the region’ in the BRA project. While not explicitly stated, already from the beginning *recycling* of the materials was normatively seen as the way to improve the system toward more ‘good’. The projects group’s thoughts were in the line of, ‘We should improve the recycling – kick start the market – to improve the system’. This tacit assumption normatively preferred optimizing systems for increasing efficiency in waste and resource handling and cycles thereof instead of, for example, producing less wastes or building with more simple and reusable materials. Focusing on the efficient cycling of wastes also reduced focus on minimizing or eliminating hazardous properties in construction materials. Indeed, often times when recycling construction materials, more hazardous materials will be introduced or retained in the built environment¹. I believe this more tacit selection of ‘recycling is good’, reinforced by the EC waste directive, has already instituted an assumption of what is good. However, even if recycling is not entirely in line with what we choose to see as good, I believe it to be a very important step on the road to many of the versions of sustainability we may see for the future. We should however

¹ Interestingly, the aspect of hazardous properties became more salient later in the BRA project when seen as a recycling market hindrance.

be more explicit in what underlies our normative thinking regarding concepts such as recycling and the waste hierarchy.¹

5.4.2 Some assumptions of the Looplocal project

Looplocal, in general, strives to improve resource (mis)management by improving the cycling of local and regional industrial materials (input and output) and waste. Some of the author's and collaborators' assumptions in establishing the cycle as envisioned in the case are:

- Optimizations of the *current* (existing) production system can lead toward normative visions of sustainable resource management.
- Best case scenarios from other contexts are, at least partially, applicable in new contexts.
- The rebound effect of increased synergies will not outweigh the benefit of realizing new synergies. See European Commission (2011b) for more on the rebound effect.
- Industrial representatives will be more prone to engage in networking activities if rough symbiosis potentials are shown to them – in contrast to other engagement acquisition methods (such as cold calling or core stakeholder approaches)
- Multi-aspect improvements, such as those presented by the National Industrial Symbiosis Program (NISP) in England are indeed resource management improvements under larger scoping conditions. For more on their benefits see Dowon Kim (2007).
- Recycling is inherently good.

Since I have already taken up the issues of 'recycling is inherently good' in the previous section, I choose to explore the assumption that 'working to optimize the resource efficiency of the current production system' is an effective method toward the aim of smarter resource management.

This assumption normatively prefers the industrial geography and institutional makeup as it stands today, or probably (with statistics being a few years old) as it stood yesterday. This approach to improving resource management, normatively assumes that there is nothing fundamentally inadequate with the current structure of human and production systems, outside their careless wasting of material and energy

¹ For more on our conceptions of the waste hierarchy and recycling see Lazarevic et al. (2012)

resources. An alternative assumption here could be that, working with the dominant contemporary production system is a necessary, medium term, act on the path to fundamentally restructured production systems.

If we return to the conversation contemplating ‘good’, this assumption of maintaining the current industrial institution may seem irrational under various definitions of the term. For example, if a different definition of good is taken up for resource management such as, ‘good resource management is keeping the background levels of substances relatively constant in the biosphere and controlling the entropy of hazardous or potentially hazardous materials’, would our procedural approach or analytical methods be in line with such an interpretation of the normative goals? Under such interpretations, the case study (and Paper III) use of the Looplocal tool might instead block improvements toward aims through the strengthening (and potentially further locking-in) intrinsically non-sustainable institutions (under the new conditions).

This doesn’t mean we need throw away our engagement based approach or the hard developed Looplocal tool if we decide to define ‘good’ with contrasting perspective. One could for example, focus the tool on existing or emerging industries that did fulfill the ‘good’ and resulting sustainability criteria. The tools could be used with aims to explicitly support emerging bio-industries that do not produce products or wastes harmful to the environment or human health in the first place. By strengthening networks, supply chains, knowledge sharing, and resource efficiency; these tools could be more explicit in their normative aims. Additionally, further industrial ecology tools could be used to evaluate and legitimize what are instead seen as ‘good’ alternative forms of production, making society less skeptical in the uptake of such networks.

5.4.3 Deeper societal assumptions of which the projects and resource management are embedded

If we look back to Ardent’s ladder of reflection in Figure 7, the top two rungs of the reflection ladder are:

- The broadly shared beliefs, values and perspectives (meta-cultural frames) typical to a societal culture
- The beliefs values and perspectives held by institutions, regimes, and interest groups

These arguments may at first seem far from the projects presented in this thesis looking at C&D and other industrial resource management in Sweden. However,

addressing and reflecting upon these meta contexts, some scientists, such as Ehrenfeld (2000), go so far as to argue that many of our problems in working toward sustainability and sustainable resource management are rooted in our collective, fundamental (and normative) societal assumptions of how things should work – our world views – our societal paradigms. This would mean these higher rung issues are very tightly intertwined with this thesis and the thesis' very normative aim of actively improving such management. In Ehrenfeld's (2000) discussion regarding what he saw as some contrasting paradigmatic aspects and assumptions behind 1) contemporary western society and 2) what he envisions as a more sustainable society, two of his comparisons are especially relevant to the presented case studies. These are paradigmatic aspects of 'technological optimism vs. technological skepticism' and 'competition vs. cooperation'. I cannot do full justice to these subjects within this space, but believe it quite worthy of the summaries in the next and final sections.

Technological optimism vs. technological skepticism

In these contrasting societal views of technology, suppositions are being made regarding the ability of technology to solve the sustainability challenges we face in our scientific, collaborative, and normative enterprises. One of the major arguments in this debate deals with the (highly relevant to this thesis) subject of technology and efficiency. If we are to become sustainable in our resource management through the increased efficiency of technologies – some scientists believe these technologies will need to be 4 to 20 times more efficient than current technologies (Ehrenfeld 2000; Weizsäcker et al. 1998). For more on the critical side of this debate see Huesemann and Huesemann (2011).

Competition vs. Cooperation

Other issues on the higher rungs of reflection of relevance to this thesis are the societal norms related to competition and cooperation. As Ehrenfeld (2000) elaborates, such cultural aspects can carry value laden terms and ideas such as communism, objectivism, freedom, progress, etc. Focusing on the presented cases and not entering a full discussion of such charged issues here within, it can be interesting to contemplate the effect of assumptions and norms regarding competition and cooperation. Questions arise, such as: *'When employing engagement processes focused on bringing together organizations with disparate objectives to collaboratively work toward collective aims, are we able to leave the concepts of competition at the door?' or 'Should an organization, in the name of cooperation, engage in processes that might eventually lead to their business model's nullification? And if so - how can we cooperate to help them in a transition to a new business model?'*¹

¹ This was an issue to some extent in the BRA project. If material cycling was to be more localized, performed at the demolition sites, participating transport companies stood to lose a large share of their C&D business.

6 CONCLUSIONS

6.1 Structured Conclusions

I structured my conclusions in direct relation to the objectives stated in Section 1.2.2.

Objective A - Establish a framework for analyzing the use of industrial ecology tools within iterative and participative methodologies.

My work during this licentiate research aimed to improve resource management in regards to multiple perspectives of sustainability. To achieve this strongly normative aim I chose to employ a highly participative action research procedure supported and informed by analytical methods from the industrial ecology toolbox. In Chapter 3, a framework was established to clarify this pragmatic combination of research methods from seemingly contrasting ontological backgrounds. This framework suggests that the post-positivist analytical methods can be seen as observing and studying steps in an iterative, focusing in, process of reflection, planning, and action.

Objective B - Demonstrate the use of a normative and participative research methodology for resource management.

Through the use one multi-phase stakeholder engagement project, and the visualizing of another such process, the use of a participative research methodology for resource management was demonstrated. The use of normative and participative methods was indeed effective in identifying areas of salience requiring improved planning for resource management (as shown in workshops I and II of the project BRA). While many of the participants in the BRA project noted in a final questionnaire that they believed the project had had a positive effect and would continue to spur sustainable change in the management of C&D materials in the region, a follow up to measuring the change in indicators would be premature at this time.

Objective C - Strategically select, employ, and display the results of industrial ecology analysis tools in facilitated cases.

From the array of industrial ecology tools available, those tools deemed most appropriate for each desired and emerging informative task were selected in accordance to the priorities identified in initial workshops of the C&D project (see Papers I and II and section 4.1). The industrial ecology tools selected were for the most part screening (broad and quick) life cycle assessments, and cost benefit analyses (See Figure 9 and Table 2). In follow-up questionnaires after BRA workshops and the BIMMS symposium the stakeholders were positive to the informative function of such tools in their learning and action processes.

For the Looplocal project, industrial ecology tools (LCI, MFA) were combined with a heuristic analysis with aims to give strategic support to symbiosis facilitation. The results of the tools first employment in a proof of concept run are shown in Section 4.2.

Objective D – Inspect some of the strengths and weaknesses of the bottom up and mixed method approach to normative research in the selected cases.

While the iterative and highly participative process of the C&D case required large amounts of time and resources for organizing and enacting (see Section 5.1.1), it resulted in producing an image of the situation that would have been difficult to ascertain otherwise. While purely descriptive methods might allow for faster and more straight-forward research, they may not have had as much of a ‘real world’ insight as the participative approach. There was a good amount of stakeholder buy in to both the analyses and the action process as exemplified by the efforts to begin a new cross-sector industry organization. However the effect of this bottom up approach as opposed to one of a direct legislative or regulative top down approach has not been compared. Perhaps, change elicited from a top down approach would be faster in spurring sustainable resource management transitions.

Objective E - Investigate the potential for information analysis in strategically supporting the facilitation of resource efficiency initiatives by developing and presenting the results of a tool.

Widening the scope of resource management from that of construction and demolition materials to embrace further industrial metabolisms, the Looplocal strategic tool (based on heuristic information analysis) was established by the author and colleagues. Together with the recycling industry, the tool has shown strategic potential in identifying 1) regions prone to applying facilitative resources 2) potential new industrial recycling networks, and 3) heightening the engagement rates of facilitation activities through proactive opportunity marketing. The results of the ICT tool are presented in Section 4.2. Integrating this tool further into the industrial arena may advance our understanding of its ability or inability to support the (highly social and interactive) creation of new resource management networks.

Objective F – Tentatively analyze the impact of the normative grounding of the cases, and discuss some of the underlying assumptions in each of the cases.

The normative grounding of the research tentatively showed to be both supportive and resource demanding within the C&D case study as shown by the participant’s responses in the post-workshop and symposium questionnaires. However, identifying and making this aspect of the research explicit may allow for a greater chance of identifying underlying assumptions of the research and focus system as wholes. These underlying assumptions (reflected upon in Section 5.4), such as the

conventional thinking of ‘recycling is always good’ may be part of the cause of the problems we are trying to address. Therefore making the tacit normative aspects of our research (such as choice of field, areas of focus, choice of methodologies, etc.) more explicit may help us to truly address the problems we strive to solve as a society.

6.2 Future research recommendations for the field of resource management

There are many topics in the area of improving resource management that merit additional research efforts. In direct relation to the research presented in this licentiate, the topics of 1) mixed method approaches, 2) ICT tools, and 3) social transitions are addressed here.

Mixed method approaches

Sustainability scientists sometimes mix methods from the various scientific paradigms presented in Table 1 to achieve their descriptive and normative aims. Further research into the scientific communities’ notion of credibility toward such approaches could be enlightening to improve such an approach. Many of the mixed methods in this licentiate were utilized in a participative, bottom-up, approach. Further research with mixed methods for resource management could compare and evaluate the efficacy of such mixed method uses in both bottom-up and top-down situations. Another useful research question in relation to mixed method approaches could be that of, *‘what is the historic efficacy of informative tools (such as LCA, and MFA) in creating desired changes in resource management?’*

ICT tools

The use of ICT tools for IS facilitation has been analyzed in Grant et al. (2010). Further research into the use ICT could compare required resource inputs and informative outputs in regards to the specific aims of such tools. For example, *is the use of tools such as Looplocal any more effective than a simple analysis of the industrial diversity (or density) of a region if identification of ‘hot spot’ regions is the main goal? or How does the use of human and financial resources stack up in regards to other specific goals?*

Social transitions

As postulated in Section 5.4.3, efficiency and technology measures may not be enough to improve resource management to desired levels. More research into social focused methods for changing consumption patterns as well as adapting social paradigms may therefore be merited. Much of the dynamics of historic social transitions has been addressed by general theories in sociology (Mahoney 2004). However, the application of such general theories for social transition is still relatively thin in regards to resource management. Looking into (comparing and contrasting) how other change oriented approaches could be applied to normative resource management would be a good next step.

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