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*OPERATIONALIZING INDUSTRIAL
ECOLOGY IN THE WASTE SECTOR*

Roles and Tactics for circular value innovation

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Doctoral Thesis

Environmental Technology and Management

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FRONT MATTER

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This work is dedicated to the memory of two strong and inspiring teachers who encouraged my passion for business development and industrial symbiosis respectively.

Graham O'Neal
(1930-2013)

&

Leo Baas
(1946-2016)

ABSTRACT

The take-make-waste approach to resource management in human production and consumption systems is contributing to a variety of environmental and social problems worldwide. Additionally, as the world's population and affluence increase, so do the negative impacts of poor resource management. Lifting the waste management (WM) sector into a new phase of development, which takes its lead from the ideals of Industrial Ecology and circular economy, is seen by many scholars and practitioners as one potential to assist in alleviating these impacts.

External (e.g. national and international policy) and internal pressures (new leading visions within Swedish WM organizations) are driving the Swedish WM sector to develop novel approaches toward more efficient resource management. While there are many studies on how more efficient inter-organizational resource management is (or could be) constructed, there are relatively few business development studies which have explored novel approaches (from roles to tactics) that WM organizations might operationalize toward more efficient resource management.

The aim of this thesis is to contribute to the development of knowledge and understanding of how the waste management sector can operationalize more effective and efficient resource management. In approaching this aim, two research questions guided the exploration of: 1) novel roles for WM and 2) support tactics for such roles. Grounded in the broader context of Industrial Ecology (IE) and Business Development, five studies were performed. Two studies, focused on the novel roles of *inter-organizational resource management* and *high value secondary resource extraction*, were performed through literature review and interviews, and market driver analysis respectively. In exploring support tactics, two design and proof of concept studies were carried out to investigate data analysis tools for inter-organizational resource management, and one long-term action research engagement project was coordinated to study hands-on inter-organizational collaboration tactics.

The studies highlighted that the Swedish WM sector holds some key capacities for operationalizing (and in some cases, is already developing) the novel resource management roles identified: industrial symbiosis facilitator, eco-industrial park manager, holistic facility management, and high value resource extractor. However, depending on the portfolio of services to be performed in such roles, several capacities may need to be developed or strengthened. Main opportunities seen for these roles were – staying ahead of market developments, and aligning activities with organizational goals. The main general risk related to these roles was insufficient returns on investment. Looking forward, the main enablers identified were policy leadership for more balanced market mechanisms, increasing use of external knowledge, developing long term partnerships, lobbying, stockpiling resources, and carefully crafting new business models.

The tools developed for strategically applying external information toward the identification of opportunities within new roles showed tactical potential. However, their implementation in broader development processes has yet to be fully validated. The hands-on exploration of change oriented collaboration, highlighted collective system framing and goal setting and face-to-face interaction as key activities for inter-organizational approaches within roles such as industrial symbiosis facilitator.

Throughout the studies, several novel roles were investigated. Each of these roles will need to be individually evaluated by directing bodies of WM organizations, and evaluated from the organization's vision and strategy. If certain roles are chosen to be explored in more detail, they will need to be developed within full business models - addressing issues such as income structure, internal processes and capacities to be developed, and key customers. Through applying IE and business development concepts and findings, WM organizations have possibilities to translate ambitious visions into novel offerings.

SAMMANFATTNING

Dagens dominerande linjära resursförvaltningsstrategi bidrar över hela världen till olika miljömässiga och sociala problem. Den bristfälliga resurshanteringens negativa konsekvenser ökar dessutom i takt med att världens befolkning och dess välstånd växer. Många forskare och praktiker ser en möjlighet att bidra till att minska dessa konsekvenser genom att lyfta avfallssektorn till en ny utvecklingsfas med inspiration från industriella ekologins och cirkulära ekonomins visioner.

Externt (t.ex. nationell och internationell politik) och internt tryck (nya visioner inom de svenska avfallsorganisationerna) driver den svenska avfallssektorn att utveckla nya strategier mot mer effektiv resurshantering. Det finns många studier om hur mer effektiv resursförvaltning kan åstadkommas genom samarbete mellan olika organisationer, men det finns relativt få affärsutvecklingsstudier som utforskat de nya strategier (från roller till taktik) som avfallsorganisationer skulle kunna använda för mer effektiv resursförvaltning.

Denna avhandlings mål är att bidra till utveckling av kunskaper och förståelse av hur avfallssektorn kan operationalisera mer effektiv resursförvaltning. För att närma sig detta mål, har två forskningsfrågor väglett utforskandet av 1) nya roller för avfallssektorn och 2) understödjande taktik för sådana roller. Fem studier förankrade i industriell ekologi och affärsutvecklingsstudier har genomförts. Två studier, baserade på litteraturstudier och intervjuer, fokuserade de nya rollerna i samband med interorganisatorisk resursförvaltning och utnyttjande av högvärdiga sekundära resurser. Dessutom genomfördes två design- och ”proof-of-concept”-studier för att undersöka dataanalysverktyg för interorganisatorisk resursförvaltning och ett långsiktigt aktionsforskningsprojekt för att studera interorganisatorisk samarbetstaktik i praktiken.

Studierna pekade på att den svenska avfallssektorn förfogar över en del av de nyckelkapaciteter som behövs för att kunna praktisera de identifierade nya rollerna: industrisymbiosfacilitator, ekoindustriparkmanager, holistisk anläggningsförvaltare och återvinnare av högvärdiga resurser. Beroende på den serviceportfölj som krävs i samband med dessa roller behöver emellertid ytterligare kapaciteter utvecklas. De viktigaste möjligheterna som identifierades i samband med dessa roller var att kunna hålla sig framkant på marknadsutvecklingen och att anpassa aktiviteterna till organisationernas mål. Generellt är den största risken kopplad till dessa roller otillräcklig avkastning på investeringarna. De viktigaste möjliggörarna kommer i framtiden att bestå av politiskt ledarskap mot mer balanserande marknadsmekanismer, ökad användning av externa kunskaper, utveckling av långsiktiga partnerskap, lobbying, resurslagring och omsorgsfull utveckling av nya affärsmodeller.

De verktyg som utvecklats för strategisk tillämpning av extern information för att identifiera de nya rollernas möjligheter uppvisade taktisk potential. Implementeringen av dessa verktyg måste dock utvärderas ur bredare perspektiv. Studierna av förändringsinriktade samarbeten pekade mot att kollektiv systemdefinition, målformulering och direkt (öga-mot-öga) interaktion har avgörande betydelse för interorganisatorisk utveckling, till exempel i samband med rollen som industrisymbiosfacilitator.

Ett flertal nya roller har undersökts i samband med de olika studierna. Var och en av dessa roller kommer att behöva ytterligare utvärdering av avfallsorganisationernas ledningar för att anpassa dem till organisationernas visioner och strategier. Om man väljer att undersöka vissa roller närmare, kommer de att behöva utvecklas inom ramen för fullständiga affärsmodeller som omfattar inkomststrukturer, interna processer och kapaciteter som behöver utvecklas och nyckelkunder. Genom att tillämpa begrepp och resultat från studier inom industriell ekologi och affärsutveckling, kan avfallsorganisationerna få möjlighet att översätta ambitiösa visioner till nya affärserbjudanden.

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During my industrial PhD studies, I have grown professionally and made many close colleagues at Ragn Sells AB. Many thanks to all from the Recyclables and AO Entreprenad departments, especially my two managers Elisabeth and Anders who supported my dual roles throughout.

Finally, this PhD work has been a large part of my life for the last eight years. I have grown academically and enjoyed the experience immensely, but not without a good share of roadblocks, frustration, and late nights. Without the support, motivation, laughs, and inspiration of my friends and family, the complicated times would have been much trickier, and for that I owe them an immeasurable amount of gratitude. Jorge, Gustav, Mario, Ewa, Nigel, Therese, Jagdeep, Rafa, Rajib, Jeremy, John, Jan, David, Grace, Bosse and Mike: you are amazing. Thank you to my parents (Kathleen 'the editor' and Toney), sisters (Hilary and Mason), and the rest of my family and friends in the US for their support and love during this period. You are the best!

I deeply enjoyed the opportunity to investigate areas so close to my desires of supporting transitions toward more sustainable resource use, and I hope very much that I may continue along this path as I persist to straddle the lines between academic and industrial practitioner.

Graham Ashby Aid

Stockholm, Sweden 2017

LIST OF APPENDED PAPERS

This thesis is based on the following papers which have been reproduced in Appendices 1 through 6. A detailed introduction to the Papers and their methods is provided in Chapter 3.3.

- Paper I:** Aid, G., Eklund, M., Anderberg, S., Baas, L., 2017. Expanding roles for the Swedish waste management sector in inter-organizational resource management. *Resources, Conservation & Recycling*, 124, pp. 85–97.
- Paper II:** Kihl, A. & Aid, G., 2014. Driving forces and inhibitors of secondary stock extraction. *The Open Waste Management Journal*, 8, pp.52–58.
- Paper III:** Aid, G., Brandt, N., Lysenkova, M. & Smedberg, N., 2015. Looplocal – a heuristic visualization tool to support the strategic facilitation of industrial symbiosis. *Journal of Cleaner Production*, 98, pp.328–335.
- Paper IV:** Davis, C., Aid, G. & Zhu, B., 2017. Secondary Resources in the Bio-Based Economy: A Computer Assisted Survey of Value Pathways in Academic Literature (*Submitted to Waste and Biomass Valorization*.)
- Paper V:** Aid, G. & Brandt, N., 2012. Improvement of aggregate cycles in Stockholm and the Baltic Region Activities and results of the BRA initiative. In *WASCON 2012 - towards effective, durable and sustainable production and use of alternative materials in construction*. Gothenburg, Sweden.

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Related Publications:

- Aid, G. & Brandt, N., 2010. Action Research in Waste Management: Application to Construction and Demolition Waste in the Stockholm Region. In *Linnaeus ECO-TECH '10. Kalmar, Sweden, pp. 1009–1019*.
- Aid, G., 2013. Industrial Ecology Methods within Engagement Processes for Industrial Resource Management. The Royal Institute of Technology (KTH). Licentiate thesis available at: <http://www.diva-portal.org/smash/record.jsf?pid=diva2:622162>.
- Aid, G., Lazarevic, D., Kihl, A., 2016. Waste to Resources: Moving toward the 2030 Sustainable Development Goals, in: Hogland, W. (Ed.), *Linnaeus Eco-Tech 2016 Proceedings*. Kalmar, Sweden.

CONTRIBUTION TO THE PAPERS

Paper I

The author was responsible for the planning, research and writing of the paper. Anderberg, Eklund, and Baas contributed in a supervisory role (from formulation to analysis).

Paper II

The author was responsible to a large degree for the analysis and writing of sections 2 through 5 and the production of Figures 3 and 4. The planning, and method development were a collaborative process between Aid and Kihl.

Paper III

The author was responsible for planning the project, design of the method, the collection of data, the analysis of results, and writing the paper. Brandt contributed in a supervisory role. Lysenkova and Smedberg contributed to the method design and data programming.

Paper IV

The author was responsible for the result analysis, and to a large degree the introduction and discussion writing. The planning and method development were a collaborative process between the author, Davis, and Zhu. Davis performed the programming.

Paper V

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 a conference. Brandt contributed in a supervisory role.

DEFINITION OF KEY TERMS

<i>Business Model</i>	“The business model is a conceptual framework for identifying how a company creates, delivers, and extracts value.” (Skarzynski & Gibson 2008, p.112). Business models address key areas such as value proposition (what), customers (who), infrastructure and processes (how), and revenues and cost structure (Markides 1999).
<i>Business Role</i>	A general collection of business activities performed toward providing certain services or products as an incorporated provision. For example: <i>IT service manager, transportation firm, facilities manager</i> , etc.
<i>Business Tactics</i>	Tactics are operations or implementation practices employed to maximize value and revenue creation within the chosen business models (Reim et al. 2015).
<i>Functional Recycling</i>	Waste materials recycled or reused in such a way as to retain their original functional properties, thereby reducing the need to extract primary materials for this function.
<i>High Value Resource Extraction</i>	The extraction of secondary raw materials from waste resources for functional recycling.
<i>Industrial Symbiosis / Inter-organizational Resource Innovation</i>	The creation of novel environmental and economic value through the cycling of resources and the sharing of services and utilities between companies in networks (Chertow et al. 2008).

LIST OF ABBREVIATIONS

AR	Action Research
BIM	Building Information Modelling
BRA	"Bygg- och Rivningsavfall"(sv) = Construction and Demolition Waste (en) In Swedish <i>bra</i> means <i>good</i>
C&D	Construction and Demolition
CAPEX	Capital Expenditure
CATWOE	Clients, Actors, Transformation, Worldview, Owner, and Environmental constraints
CBA	Cost Benefit Analysis
CE	The Circular Economy
DfE	Design for Environment
ICT	Information and communications technology
IE	Industrial Ecology
IS	Industrial Symbiosis
ISDATA	The Industrial Symbiosis Data platform hosted on isdata.org
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Inventory
LDA	Latent Dirichlet Allocation
MALLET	MACHine Learning for Language Toolkit
MFA	Material Flow Analysis (Accounting)
OPEX	Operating Expenditure
ROI	Return on Investment
SFA	Substance Flow Analysis (Accounting)
SLCA	Social Life Cycle Assessment
SV	In Swedish
TAPs	Technologies, Applications or final Products
WEEE	Waste Electrical and Electronic Equipment
WM	Waste Management

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CHAPTER

ONE

1 INTRODUCTION, AIM, AND RESEARCH QUESTIONS

This chapter begins by describing the course of global resource use and the general problems associated with this trajectory. Subsequently, the central actor of study focus for this thesis, the waste management branch, is introduced alongside research and practitioner activities from the field of Industrial Ecology. The groundwork for the motivation for thesis is outlined, followed by the aim of the work and the specific research questions. This chapter concludes by providing an outline of the thesis document.

1.1 INTRODUCTION

The amounts of raw materials (biomass, metals, non-metallic minerals) fueling the world economy are staggering; some 84 billion tons entered the economic system in 2013 compared to 36 billion tons in 1980 (SERI & WU 2016). The world population grew during this period, and at the same time world per capita material consumption¹ also grew from 8.1 tons per capita to 11.7 tons per capita (SERI & WU 2016). In addition to population expansion, economy wide material consumption is propelled by economic growth and affluence (Krausmann et al. 2008). Both affluence² and population are expected to continue their rise in coming decades, setting the stage for substantial growth in virgin material demand if major changes are not made to our approaches to production and consumption (Krausmann et al. 2008; McKinsey Global Institute 2011; Ellen MacArthur Foundation 2012; UN 2015b).

Humanity receives a lot of good from our resource use, such as food, housing, clothing, transportation, sanitation, and energy. Indeed, we will need more of these goods and services going forward if we are to provide a decent standard of life for everyone. However, the linear ‘take-make-waste’ use of our material resources in combination with growing economies has led to increasing amounts of post-consumer waste, increasing need for resource extraction, and growing greenhouse gas emissions (Lacy & Rutqvist 2015). The effects of these trends can cause great detriment to the environment and its inhabitants (Blanchard 1992; Chertow 2000b; Wenheng & Shuwen 2008; Gerbens-Leenes et al. 2010; Singh 2016). Additionally, our resources are not unlimited, only about 27% of the 84 billion tons of resources entering the global economy today can be considered renewable (SERI & WU 2016). This is leading toward a situation of increasing scarcity of many of the materials we use today (McKinsey Global Institute 2011; Singh 2016). Continued mismanagement of these resources will further drive environmental and scarcity problems which threaten current and future generations’ ways of life, health, and even political stability (Ross 2002; World Bank 2002; Dobbs et al. 2013).

¹ This is economy wide Raw Material Consumption (RMC) which does not include materials such as mining waste from primary production which do not enter the economic system. As we are looking at world consumption here Raw Material Consumption = Raw Material Input. For clarification of these indicators see Figure 2 in (Bringezu 2015).

² By 2030 up to 3 billion more middle-class consumers are expected in the world (McKinsey Global Institute 2011).

Within this broader problem situation, the Waste Management (WM) sector in Sweden was chosen as a central actor to research within this thesis. Many believe that evolving the WM sector into a new phase of development has potential to assist in alleviating problems stemming from our resource mismanagement while at the same time creating added resource value for the economy in general (EC Environment 2011; EEA 2014; Lacy & Rutqvist 2015; Wijkman & Skånberg 2015; The Nordic Competition Authorities 2016). A central tenet of this thesis is that, via novel business approaches, WM organizations might actively assist in a shift toward the use of more renewable resources, less environmentally harmful technologies, more resource efficient technologies, cross-sector systems' solutions, and value added circular resource management.

To further explore what this new phase might entail, findings and insight was sought from academic disciplines which have emerged in recent decades in response to resource related concerns. Among these disciplines, the field of Industrial Ecology (IE) has spearheaded many studies into resource, and interrelated, issues via systemic analysis of our socio-technical systems (e.g. material, energy, and substance flow studies) and via design oriented activities (Lifset & Graedel 2002). While there are many studies in the IE cannon on how more effective and efficient resource management is (or could be) constructed (van Berkel & Lafleur 1997; Ayres & Ayres 2002; Singh 2016), there are relatively few studies which have explored novel business approaches that WM organizations might operationalize toward more efficient resource management.

From a business development perspective, most of the analytical and application focused methods in the IE toolbox hold 'tactical' potential for the WM branch³. For example, two novel areas highlighted by researchers in IE focus on multi-stakeholder engagement in complex development situations (Aid 2013) and information support for circular services (Grant et al. 2010; Nilsson & Baumgarten 2014). However, such tactics may only realize their potential in business operationalization when they support specific roles which have been strategically chosen and pursued by an organization (Stampfl 2016). Therefore, to further study how WM organizations might make a shift from business-as-usual⁴ toward operationalizing novel resource management activities a two-fold approach can be valuable - studying potential roles of WM and tactics that might support such roles.

³ Tactics are operations or implementation practices employed to maximize value and revenue creation within an organization's chosen business models (Reim et al. 2015).

⁴ From, for example, a heavy focus on landfilling and commodity recycling to that of circular resource management and cross sector solutions.

1.2 AIM AND RESEARCH QUESTIONS

Aim of the work

This thesis aims to contribute to the development of knowledge and understanding of how the waste management sector can operationalize more effective and efficient resource management.

Pursuant to this aim, two main research questions were developed which center on the WM sector as a study focus. These questions focus on exploring potential roles for WM firms in working toward higher value resource circulation, and tactical methods to support such roles. In pursuing 'higher value' circulation, value can be gauged via efficiency and effectivity respectively. For example, in operationalizing more efficient resource management, value can be created by producing the same or more outputs with fewer new inputs or reducing resource entropy. Whereas in operationalizing more effective resource management value can be created when activities move toward one or many particular (individual, organizational, society wide) purposes, such as improving ecosystem health, generating profits, creating jobs, etc.

Research Question I (RQI) - Roles

What novel roles are available for Swedish WM firms to assist in more effective and efficient resource management?

RQ1 addresses the novel approaches a WM firm could engage in toward the goal of improved resource management. Specifically, RQ1 seeks to explore activities other than sanitation and the business-as-usual production of recycling commodities (such as metal, plastic, and paper) by WM. In approaching this question, the core competencies of waste management organizations, risks and opportunities of new functions, and market factors are significant to the ability of WM organizations in approaching new strategies and roles

Research Question II (RQII) - Tactics

What are potential business tactics available to support novel roles for WM firms?

RQII addresses certain support tactics that could be employed within the operationalizing of novel roles. RQII focuses on two specific areas - *information support for circular services* and *multi-stakeholder engagement and development* - in studying tactics.

Information support tactics for circular services

The study of tactics for information support looks toward how various information sources might assist WM organizations in performing novel circular roles and specifically seeks to address the sub-question, “How *can the WM industry make use of internal and external information to identify new value creating opportunities and assess potential circular services?*”

Multi-stakeholder engagement and development tactics

Based on the findings that single stakeholders do not always have the ability to implement sustainable solutions on their own in complex systems (Seager et al. 2012), the tools WM organizations can use to collaboratively identify and develop more effective solutions within multi-stakeholder systems are of particular interest in this thesis. As such, a second sub-question was formulated, “How *and with what tools can WM companies more effectively collaborate with external organizations toward the aim of increasing regional circularity and private competitiveness?*”

1.3 THESIS OUTLINE

This dissertation is a compilation thesis comprised of a cover essay (the current document) followed by a collection of academic articles which have been authored or co-authored by myself. The ambition of the cover essay is to present and discuss the thesis work as a whole, while the articles explore specific research questions in more detail.

Chapter 1 introduces the general problem area addressed in the thesis, the general research gaps and drivers motivating the focus and aim of the thesis. These are followed by the aim and research questions for the thesis work.

Chapter 2 introduces the central concepts guiding the thesis (Industrial Ecology, Industrial Symbiosis, and Business Strategy and Development), as well as a background to the Swedish WM sector, the industry sector of focus.

Chapter 3 presents the general approach taken in this thesis, summarizes the five appended papers per their relation to the cover essay, and presents the broad toolbox of methods applied within these studies.

Chapter 4 presents the results of the studies in relation to thesis. This chapter structures the presentation of results after the main research questions addressing roles and tactics.

Chapter 5 takes a step back and discusses what the results of the work mean in regards to the research questions and how these results relate to other research in the Industrial Ecology and Business Development fields. This is followed by an evaluation of the overall research approach and a presentation of future research gaps and challenges.

Chapter 6 provides a final summary conclusion of the thesis work.

Appendices I-V, contain authored and co-authored articles relevant to the research questions of the thesis. While the methods and results from the various articles are summarized in this cover essay, these articles should be referred to for details surrounding the methods and results, as well as to garner a more complete understanding of the studies performed toward the aim of this thesis.

“Business is the economic engine of our Western culture, and if it could be transformed to truly serve nature as well as ourselves, it could become essential to our rescue.”

Karl-Henrik Robert, Founder of The Natural Step
(Natrass & Altomare 1999, p.XIV)

CHAPTER TWO

2 BACKGROUND

This chapter introduces the central concept of Industrial Ecology (IE) and its tenets, followed by the research areas of Industrial Symbiosis (IS) and Business Strategy and Development. Additionally, a presentation of the organization, activities, and development of the Swedish WM sector is provided.

2.1 INDUSTRIAL ECOLOGY

IE is a relatively new field which seeks to analyze and address, among other things, the metabolism of human production and consumption systems (Graedel & Allenby 1995). The term “Industrial Ecology” was popularized by Frosch and Gallopoulos (1989), and early in its development, IE began to apply a wide systems perspective as expressed by White’s (1994, p.V) definition:

“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 first textbook on IE by Graedel and Allenby (1995, p.9), where IE 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.”

The field of IE holds several central tenets for industry, such as *fostering inter-organizational cooperation for circular waste valuation, balancing industrial metabolisms to interface safely with nature, the conservation of resources used for production, development of renewable energy and material supplies, the integration of economic and environmental accounting, and the creation of new structures for coordinating action, information exchange, and communicative linkages* (Tibbs 1992; Ehrenfeld & Gertler 1997). A more specific focus within the tenet of conservation of resources used for production is that of promoting *functional recycling* where the full function of a material is retained and utilized in its next use phase (Graedel et al. 2011).

The IE field has a broad methodological toolbox which includes *analytical* and *application* (design) oriented methods (Lifset & Graedel 2002). Analytical methods, such as material flows accounting (MFA), substance flow accounting (SFA), and life cycle assessment (LCA), are used to study resource stocks and flows, and at times the impacts of resource use. Additional analytical methods, including cost benefit analysis (CBA), life cycle costing (LCC), and social life cycle assessment (SLCA) are tools employed in IE to improve knowledge of the social and economic aspects of systems. These analytical methods lean

toward descriptive science, however issues such as systems scoping, method choice, indicator choice, and indicator weighting can impart subjective or normative aspects to these tools. Application focused methods of IE include explicitly change focused actions such as Design for Environment (DfE) activities, Eco-Efficiency activities, and planned/facilitated Industrial Symbiosis (IS). Figure 2-1 presents the analytical and application based activities of IE as conceptualized by Lifset & Gradel (2002).

Figure 2-1 Industrial ecology conceptualized in terms of its system oriented and application oriented elements (Lifset & Graedel 2002)

Addressing IE and WM in the 2002 Edition of the Handbook of Industrial Ecology, Clinton Andrews noted, (Andrews 2002, p.553)

“The challenges for the new century are to improve the adaptability of the public management system and to reintegrate private sector and non-profit initiatives without increasing health or ecological risks. Industrial ecology provides a helpful systemic perspective and criteria for better waste management, but it offers less guidance on implementation issues.”

Academics in and next to the field of IE have started to fill in this gap, from systemic perspectives to implementation, through exploring inter-organizational innovation, green innovation, network processes, technological change, policy and market factors, and a host of IS and eco-industrial park cases (Opoku 2004; Stift 2011; Tsvetkova & Gustafsson 2012; Roos 2014; Walls & Paquin 2015; Singh 2016; Spekkink 2016). Still, relatively few studies have gone deep into exploring novel implementation approaches (including business roles and tactics) that WM organizations specifically might take toward the normative circular tenets of IE.

2.2 INDUSTRIAL SYMBIOSIS

IS has been described as a sub-field of IE which focuses in particular on the creation of novel environmental and economic value through the cycling of resources and the sharing of services and utilities between companies in a regional network (Chertow et al. 2008). There are many definitions of IS, however, in general, mutually beneficial collaborations between a diversity of industries, often in geographic proximity, are core to the concept (Chertow 2000a, p.314; Lombardi & Laybourn 2012). The key aspects of novel resource use, geographic proximity, broader resource/service inclusion, and innovation systems (as contrasted with specific technologies in isolation) can help in differentiating between industrial symbiosis and traditional waste management development.

The IS network in Kalundborg, Denmark is frequently referred to as the archetypical IS network. Numerous aspects of this network have been studied by a range of IE practitioners over the years (Ehrenfeld & Gertler 1997; Chertow 2007; Branson 2015). Since collaborations began in 1961, 30 symbiotic projects have been realized in Kalundborg, cycling and valuing resources such as steam, process water, protein rich by-products, and fly ashes (Branson 2015)⁵. Kalundborg is but one of many various examples of IS around the world which range in size, resource focus, types of resource transfers, and governance structures (Massard et al. 2014). A few examples of individual innovative symbiotic relationships are: the use of coal fly ash as a binding agent in construction materials (Ammenberg et al. 2015), the use of surplus industrial heat in external organizations' production processes (Chae et al. 2010), the use of exhaust gas from an energy facility to supply needs of a greenhouse (Jaffrin et al. 2003), or the sharing of surplus warehousing space between exclusive industries (Corder et al. 2014). Singular innovative relations do not fulfill the networked and systemic aspect of IS alone.

This concept of Industrial Symbiosis (IS) is both a *subject of analysis* and an *application focused* method of IE.. As a research subject, *analysis* methods from IE along with methods from sociology, organization studies, and political science have been used to study IS (and its development) in various forms⁶ (Spekkink 2016). Such analysis studies seek to describe, analyze, and reflect upon issues such as how networks IS come about, what are the

⁵ For a summary of the symbiotic projects in Kalundborg see Table 1 in (Branson 2015, pp.4346–4348).

⁶ IS networks have been described as self-organized, planned, or facilitated depending on their development (Paquin & Howard-Grenville 2012)

environmental/economic impacts or savings of specific cases, or what are the limiting and enabling factors to IS implementation⁷.

On the other hand, the planning and facilitation of IS is an *application* focused method of IE. In these normative application approaches, the results from the analysis of IE, along with other design methods such as DfE, Cleaner Production indicators and guides, planning guidelines, and various information and communications technology (ICT) tools, are often utilized (or developed to be utilized) as support tools for the planning and facilitation of IS (van Berkel et al. 1997a; Grant et al. 2010).

2.3 BUSINESS STRATEGY AND DEVELOPMENT – FROM VISIONS TO TACTICS

Business strategy and development encompasses a cross-functional web of management and operational processes aimed at improving the performance of a firm. Most research, and in turn most definitions, on business processes focuses on individual parts of this web (Garvin 1994). Researchers may address areas such as strategy (via e.g. strategic management studies) innovation and development (via e.g. innovation management and business model innovation studies), or specific tasks such as product and service innovation. Studies in these areas coexist in complementary, interdependent relationships between themselves and with broader disciplines such as marketing, economics, sociology, and management (Nag et al. 2007). This section presents a cross-section of these areas to give a procedural understanding of the concepts and how they interrelate to form business strategy and development as applied in the thesis.

The business strategy and development process often starts very broad and becomes more applied as one moves further into the process. The process frequently stems from a vision which informs and shapes business strategy (Collins & Porras 1991). Business strategy in turn shapes and informs business models. Resultantly, tactics are used to strategically support the business models. The interaction of these processes is illustrated in Figure 2-2. It is on the level of tactics (or in interplay with tactics and business models) that specific product and service innovation processes (such as Stage-Gate™) are performed (Cooper 1990; Casadesus-Masanell & Ricart 2010).

⁷ Spekink (2016, pp.33–39), gives an extensive overview of literature related to IS regarding subject areas such as IS frameworks and theories, typologies, methodologies, case descriptions, models, evaluations, and normative frameworks.

Figure 2-2 The interaction of activities within business strategy and development.

Vision

The vision of an organization is the over-riding idea of what the organization should be. The constituents of this over-riding idea vary widely among both academics and organizational managers. In an effort to add clarity to the subject, Collins and Porras (1991) put forth that that vision consists of two major components: a guiding philosophy (principles, motivating assumptions, values, and tenets) and a tangible image (a mission focusing on the efforts of the organization including a vivid and engaging description). In practice, relatively few organizations fully address these components⁸.

⁸ See Collins and Porras (1991) for some examples of well-formed as well as less than sufficient vision statements.

Strategies and Business Models

The concepts of strategies and business models have been labeled as “among the most sloppily used terms in business; they are often stretched to mean everything – and end up meaning nothing” (Magretta 2002, p.9)⁹. However, the terms have steadily taken on more definite and unique meanings (Zott & Amit 2008; Stampfl 2016). In brief, strategies are how an organization is going to do better by being different (Magretta 2002). Strategies are more externally oriented, focusing on the business landscape and in turn shaping competitive positioning (Chesbrough & Rosenbloom 2002; Zott & Amit 2008).

On the other hand, business models focus on the activity system itself – the mechanisms of creating, delivering, and capturing value (Chesbrough & Rosenbloom 2002; Zott & Amit 2008). Business models address key areas such as value proposition (what), customers (who), infrastructure and processes (how), and revenues and cost structure (Markides 1999). As such, business models, “act as a strategy ‘enabler’, supporting the implementation of the company’s strategy” (Onetti et al. 2012, p.360). The choice of a business models is a key element of organizational strategy, and in turn the selection of business models determines the tactics available to a firm (Casadesus-Masanell & Ricart 2010). Our focus on *roles* in this study are roughly equivalent to that of the value proposition (the key activities ‘what’) of a business model. As such, a heavier focus is placed on ‘what’ than the ‘who’ or the ‘how’ in this thesis.

Tactics

Tactics are operations or implementation practices employed to maximize value and revenue creation within the chosen business models (Reim et al. 2015). Tactics such as promotional initiatives, branding, market analysis, targeted lobbying, and pricing initiatives may focus on maximizing the value creation of current offerings with little change to the product or service. Other tactical approaches, such as product and service development, strategic partnerships, joint ventures, and acquisitions may be applied when developing new products and services or entering new markets. Roberts (1992) presents a framework (an adapted familiarity matrix) for assessing tactical approaches to entering new ventures. Roberts’ framework, and these broader tactical options are revisited in the discussion. However, as this study is focused on the identification, development, and implementation of resource management services; a large amount of attention herein is concentrated on product and service innovation tactics.

⁹ The perspectives laid out by Zott & Amit (2008) and Stampfl (2016) are drawn from for the brief introductory purpose here. For more perspective on business models and strategy see (Seddon & Lewis 2003).

Product and Service Innovation Tactics

An organization that has chosen to provide their customers with continually improved¹⁰ or novel products and services may choose to apply product and service innovation tactics (as opposed to e.g. acquisitions). A simplified linear chain¹¹ which lays out some of the activities within pre-development, development, and post development is presented in Figure 2-3. While performing product or service development is a tactic in itself, there are several supporting tactics that aim at assisting in the individual activities within these development activities (such as identification tactics or testing tactics) as well as tactics to approach the broader development process chain such as the Stage Gate® system (Cooper 1990).

Figure 2-3 An abridged model of the product innovation process (Lager 2000; Lager 2016)

A growing body of literature has come to recognize the importance of social learning processes (vs purely in-house processes) within innovation activities (Mirata & Emtairah 2005; Lager & Storm 2013; Hållstedt 2016). Often classified as *inter-organizational development* or *application development*, these tactics involve upstream and downstream value chain stakeholders as well as landscape stakeholder in core activities within the development and innovation processes (Lager 2016).

Another tactic supporting product and service development is process development which aims to improve the internal activities to develop and introduce cost-efficient process technology in the production processes (e.g. improving the process for regenerating waste oil) (Lager 2002).

This thesis builds upon the general framework laid out in this section, taking a specific focus on roles (the ‘what’ in business models) and on potential tactics to support novel roles for Swedish WM, which is introduced in the next section.

¹⁰ Improved’ could be in relation to quality, environmental impact, price, ease-of-use, etc.

¹¹ As with business development (vision to tactics), there are many in the field that argue that product and service innovation is not a linear process (Kline & Rosenberg 1986; Hage & Hollingsworth 2000).

2.4 THE SWEDISH WM SECTOR

Swedish WM is a study subject of focus for this thesis. While the administrative and management structure of Swedish WM is similar to other countries in Europe and around the world, it does have unique characteristics and contextual elements.

In Sweden, household waste and comparable waste from other origins is the legal responsibility of local municipalities (Waste Sweden 2014b). Municipalities can choose to perform these duties by either procuring services from private or other public actors or delegating these activities to organizations that they wholly own or own in conjunction with other municipalities.

For industrial (construction, manufacturing, energy, agricultural, etc.) and hazardous wastes, the selection of treatment provider is open for waste producer, who may choose from available private and public options on the market. There are many examples of public-public, private-public, and private-private collaborations in the Swedish WM sector. However, at the same time, there is strong competition between the public and private sectors regarding who has the rights to which waste resources. There is a debate around the extent to which public organizations should be involved in WM, given the well-established regulatory frameworks for waste management and the anticipation of the sector to increasingly shift toward a phase of resource valuation and circulation (The Nordic Competition Authorities 2016). The dichotomy of private and public Swedish WM organizations is highlighted by the formation two separate trade organizations, the majorly public 'Swedish Waste Management' (Avfall Sverige) and the private 'Swedish Recycling Industries' Association' (Återvinningsindustrierna).

In addition to these organizations, there are privately run extended producer responsibility schemes for the collection and processing of specific materials such as WEEE (Waste Electrical and Electronic Equipment), packaging and newsprint, batteries, and end of life vehicles (Swedish Ministry of Environment 1998).

Popular media often praises Sweden for having a 99% waste diversion rate (Medlock 2016; Sheffield 2016). This rate is true of the 4.7 million tons of household waste in Sweden – of which 15% is sent to biological treatment, 48% for heat and power production, 35% for material recycling, and less than 1% to landfill (Avfall Sverige 2016). In addition to household waste, around 28 million tons of industrial wastes (excluding mining waste) are generated yearly (Naturvårdsverket 2016). **Error! Reference source not found.** shows the final treatment methods (in tons) of household and industrial waste (exclusive mining waste) for Sweden in 2014.

Figure 2-4 Tons of hazardous and non-hazardous waste (household and industrial – excluding mining) sent for various treatments in Sweden in 2014 (Naturvårdsverket 2016).

*Material sent to backfilling and construction is dominated by inert material such as soils and concrete.

The development of WM in Sweden has followed the successive framings of waste, where waste has been framed as a sanitation problem (Phase I), as a sanitation and a spatial problem (Phase II), and more recently as an environmental problem (Phase III) (The Nordic Competition Authorities 2016). Much of the contemporary policy, regulation, infrastructure (such as sanitary landfills, incineration and integrated logistics), and management structure around waste has focused on mitigating these problems. Progress has been made in addressing these issues, and as a result many organizations now see space for an emerging fourth phase which focuses on the opportunities that lie in the resource value of waste (The Nordic Competition Authorities 2016). These opportunities, along with external pressures (e.g. increasing competition, decreasing returns, national policy, changing markets) are a few of the factors leading some Swedish WM organizations to

adjust their organizational visions and strategies toward broader environmental and circular resource management. A few (translated) examples of Swedish WM Organizations’ refocused vision statements and strategies are shown in Table 2-1.

Table 2-1 The visions and public strategies of three Swedish WM organizations

Organization	Ragn Sells	Tekniska Verket	NSR
Public / Private	Private	Public	Public
Vision	<i>To be living proof that caring for the earth and good business go hand in hand</i>	<i>Our vision is high - we want to create the world's most resource-efficient region</i>	<i>The goal is that our business will be a part of creating a sustainable and ecocycle-based society</i>
Public Strategy ¹²	To offer innovative and effective solutions to minimize, manage and transform waste into resources.	Linking production chains and creating connections between different parts of our business.	To be a company with extensive experience and expertise in the planning, collection, recycling and treatment of materials that others see as waste.
Citation	(Ragn-Sells AB 2014)	(Tekniska Verken 2016)	(NSR 2016)

Looking at the visions and strategies in Table 2-1, it is clear that both efficient (e.g. more with less) and effective (toward specific goals) resource management is key to success. To guide the development of this new phase, several Swedish WM organizations have adopted models and visions for more sustainable resource management such as the Circular Economy as put forth by the Ellen MacArthur Foundation (2012) and facilitated Industrial Symbiosis (IS) (Chertow 2000a; Paquin & Howard-Grenville 2012; Waste Sweden 2014a).

¹² Organizations may have several strategies (e.g. low cost provider, technology leader, etc.) that are not explicitly communicated to the public, but pursued internally.

Figure 2-5 An adapted version of Ragn-Sells' concept of the Circular Economy highlighting the traditional roles of the WM sector ©Ragn-Sells AB

These concepts have very attractive goals and offer a few case studies for a diversity of industries (KIKOX 2013; Massard et al. 2014; Lacy & Rutqvist 2015; Ellen MacArthur Foundation 2016; NISP 2016). However, more concrete approaches to how the WM branch (whose traditional role is at the lower-center of Figure 2-5) can create new economically robust roles in circular and more efficient resource management is still underdeveloped in academia and in practice (Kiser 2016). To work toward their new visions WM organizations will need to look at business models (existing and new) which involve the enactment of various value propositions (roles) (Lager & Storm 2013; Singh et al. 2014; Lacy & Rutqvist 2015; Kiser 2016). In parallel, such organizations will need to evaluate and select their tactical approaches to fulfilling desired novel roles.

CHAPTER
THREE

3 RESEARCH FRAMEWORK, STUDIES, AND METHODS

The chapter begins by presenting the overall framework for investigating business roles and tactics for the WM branch within the context and tenets of IE. Next, the approach (inquiry paradigm and procedure) to the studies is laid out, followed by a summary of the appended papers and the respective key methods applied in each study. Figure 3-1 illustrates the general focusing-in flow of the research as well as the layout of Chapter 3.

Figure 3-1 An overview of Chapter 3

3.1 THE RESEARCH FRAMEWORK

As outlined in the background, progress has been made in the field of IE in studying (among many other things) the resource situation, the interactions of resource use on our broader ecological, economic, and social systems, and improvement activities and alternatives for facilities, organizations, and regions. At the broadest level, the thesis is normatively founded within the central tenets of IE (see Chapter 2.1), above all the two tenets of *fostering circular resource management* and *the conservation of resources used for production* (specifically via functional resource cycling). Within this IE foundation, a specific focus is placed on the WM industry as a key actor of interest. Furthermore, concepts from business strategy and development (particularly the aspects of roles and tactics) are applied in exploring approaches for the WM branch as illustrated in Figure 3-2.

Figure 3-2 The embeddedness of the thesis framework

3.2 STUDY APPROACH

In selecting studies and consequent methods to approach the research questions, this thesis utilized a pragmatic approach toward normative objectives¹³. The pragmatic approach has been defined as:

“a deconstructive [research] 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 & Teddlie 2003, p.7).

While pragmatism as a philosophy has been in discussion since the late 19th century (James 1898), its application to research and the clarification of mixed methods approaches is relatively recent (Crotty 1998; Teddlie & Tashakkori 2008). One is performing mixed method research when a combination of qualitative and quantitative methodologies, methods, concepts or terminology are included in a single study (Brewer & Hunter 2005; Teddlie & Tashakkori 2008). Fundamental for mixed method research is placing the research question first.

From the problem context and research gap detailed in this thesis, two main research questions were formulated:

1. *What novel roles are available for Swedish WM firms to assist in more effective and efficient resource management?*
2. *What are some potential business tactics available to support novel roles for WM firms?*

To focus studies into novel roles, two general areas were selected for deeper examination via the two prioritized tenets of IE¹⁴ - roles for inter-organizational resource management and the role of high value resource extraction from waste. Improving the understanding of risks, opportunities, and market factors related to novel roles were outlined as areas for deeper examination. The work presented in Papers I and II studied the novel roles available for the WM sector in inter-organizational resource management and high value resource extraction respectively.

¹³ This research is normatively driven given that it actively strives to create improvements in relation to the resource dilemmas our society currently faces. More specifically, the tenets of Industrial Ecology were chosen as a key normative trajectory toward ‘what ought to be’.

¹⁴ 1) Fostering inter-organizational cooperation for circular waste valuation and 2) the conservation of resources used for production (specifically via functional resource cycling)

In focusing the studies into business tactics to support novel WM roles, the general areas of 1) making use of external information to identify new value creating opportunities, and 2) tactics for more effectively collaborating with external organizations, were selected. In researching these tactical areas, three studies were performed (Papers III, IV, & V) through hands-on-design and experimental approaches. A summary of the approaches taken to study the two research questions are presented in Table 3-1.

Table 3-1 General approach to the research questions via studies detailed in Papers I-V

	Novel Roles		Tactics	
Research Question	RQ1 inter-organizational roles (IS inspired)	RQ1 high value resource extraction role	RQ2.1 information support	RQ2.2 multi- stakeholder engagement and development
Paper	Paper I	Paper II	Papers III&IV	Paper V
General Approach	Study novel inter- organizational roles, risks and opportunities of new functions, and market factors	Study the pre- identified role of high value resource extraction, risks and opportunities of new functions, and market factors	Study, Design, and Proof new inter- organizational support tactics via prototyping	Study, Design, and Evaluate multi- stakeholder engagement approaches and key success factors via case study

While all the studies focused on improving efficiency via resource conservation (less waste/more production with existing resources), effectivity was addressed in larger degrees in Papers II and V. Paper II addressed effectivity via focusing on the specific purpose of reducing the impacts of virgin resource extraction via functional recycling. Paper V outlined effectivity via the collective goal and sub-goals (economic, environmental, etc.) of the multi-stakeholder group.

Within the individual studies various qualitative and quantitative methods were used. Methods from the IE analytical toolbox such as *MEA* were employed alongside *literature review*, and *interviewing* to feed into application oriented approaches. *Data Analysis* tools (e.g. topic modelling and co-occurrence analysis) were employed to explore the potential of novel tactical decision support tools in Papers III&IV. The research detailed in Paper V stretches furthest in applying the results of various analytical methods as tactical support within a collaborative action oriented project. In parallel, tactical *collaboration tools* to support

such inter-organizational initiatives were applied and evaluated. The methods employed in addressing each of the research questions, and the corresponding papers reporting on the respective applications, are presented in Table 3-2 and summarized in the following section.

Table 3-2 Summary of methods used for the studies described in the papers

Methods	Roles	Tactics
Literature Review	PI, PII	PIII, PIV, PV
Interviews	PI	PV
Design and Data Analysis		PIII, PIV
Collaboration Methods		PV
Material Flow Analysis (MFA)		PIII, PV

3.3 SUMMARY OF THE APPENDED PAPERS AND THEIR METHODS

Below, brief summaries of the appended papers are given alongside an introduction to the key methods utilized in each respective study. It can be useful to keep in mind that this document will not focus on the details of the methods and results of each individual study. Herein, the general insights gained from the five studies will be lifted in relation to the main research questions posed in the thesis. Therefore, the reader is encouraged to refer to the papers for more complete understanding of the individual studies, their activities, specific results, and focused discussions.

Paper I

Aid, G., Eklund, M., Anderberg, S., Baas, L., 2017. Expanding roles for the Swedish waste management sector in inter-organizational resource management. Resources, Conservation & Recycling, 124, pp. 85–97.

Paper I aimed to explore and evaluate potential inter-organizational resource management roles for WM organizations. This task was approached via *literature review* and *semi structured expert interviews* with six executives from Swedish public and private WM organizations. The interviews focused on the areas of 1) perceived capacities of WM organizations to assist in overcoming barriers to inter-organizational resource management, 2) current inter-organizational resource management activities of the studied organizations, 3) opportunities and risks of novel activities, and 4) potential tactical activities to support potential roles.

The study found that managing representatives of Swedish WM organizations believed their companies held many key capacities for assisting in overcoming barriers to inter-organizational resource management. Several of the organizations included were beginning to develop new offerings around roles such as eco-industrial park management and holistic facility management. Opportunities perceived in developing new roles included staying competitive and realigning activities to strategic goals, while some risks such as poor return on investment and supply risks were noted. Building strategic partnerships, making better use of available knowledge, adapting and building new business models, and lobbying for better market conditions were highlighted as potential support services for such novel roles.

Methods of Paper I

Paper I is primarily based upon a literature review and interviews with WM experts. This study expanded upon an extensive literature review by Nilsson & Baumgarten (2014) in order to identify barriers to inter-organizational resource management, and in turn elicit potential capacities the WM sector might possess toward overcoming such barriers. Barriers identified in the literature were placed into five barrier categories: economic, social technological, information related, and policy related.

Semi-structured, in-depth interviews with six WM executives were performed to add external insight and validation into value chain management roles which Swedish WM firms do, or could, play in overcoming barriers to improved inter-organizational resource management. Four initial interviews were selected from Sweden's largest public and private WM organizations. Further interviewees were added via references from the national waste management council (Waste Sweden) and experts in the branch.

Before the interviews, a list of barriers was identified based on the research on barriers to IS implementation. This list was used as a framework for the interviews. During the interviews guidelines from Weiss (1994) were applied. The focus of the interviews was initially put on each respective organization's current approach and potential novel approaches to aiding development in the area. Subsequently, the opportunities, threats, and success factors related to these potential approaches were addressed.

During the analysis of the interview notes and recordings, emerging topics were marked with one or several tags per areas of relevance. Details from each topic group were then assembled from across all the interviews to build topic blocks. This approach allowed for the distillation of the major topic areas in the result and discussion sections of Paper I.

Paper II

Kibl, A. & Aid, G., 2014. Driving forces and inhibitors of secondary stock extraction. The Open Waste Management Journal, 8, pp.52-58.

There are relatively few examples of true functional recycling where high value virgin materials are substituted by secondary materials, even though enabling technology is available. To explore this situation, Paper II analyses market factors for WM organizations that strive toward performing the role of high value secondary stock extraction. The paper analyzes how secondary extraction viability is dependent on factors such as primary extraction costs and resource value over time, alternative secondary value pathways, risks for necessary future remediation in poorly performed cycling alternatives, and Swedish regularity instruments such as the landfill tax on material extraction byproducts. Possible approaches for reducing some of the main barriers and potentially improving the viability of secondary stock extraction, such as lobbying for better secondary raw material market conditions and developing safe-strategic stockpiles, are discussed.

Methods of Paper II

Paper II is based upon literature review and market scenarios comparisons. Initially, a literature review to assess the economic opportunities for WM firms to extract high value critical materials from secondary stock was performed. Specifically, literature on market trends for virgin ores, material criticality, and market risks were collected and evaluated. This was done to place the research within the context of wider systems activities, set the stage for the introduction and problem formulation sections, summarize research on issues such as material criticality and increasing producer risk in Sweden, and provide external perspectives for discussion and reflection.

Two scenario comparisons were performed. To begin, a rough comparison of scenarios for virgin materials and secondary stock substitutes was performed and illustrated. This comparison, shown in Figure 3 of Paper II was based on the trends of 1) available virgin ore grade decreasing over time, and in turn increasing the energy and overall cost to extract virgin materials, and 2) technological development steadily decreasing the cost for extraction of substances in secondary stocks. The second scenario comparison (Figure 4 of Paper II) was based on the total value of secondary stock extraction in three regulatory scenarios as compared to the total value of alternative use pathways. The economic impact of the various regulatory scenarios on total value was confirmed in conjunction with Swedish WM professionals. Finally, a trend analysis, using data from the Swedish Environmental Agency, was performed to illustrate the increasing risk of alternative recycling options over time.

Paper III

Aid, G., Brandt, N., Lysenkova, M. & Smedberg, N., 2015. Looplocal – a heuristic visualization tool to support the strategic facilitation of industrial symbiosis. Journal of Cleaner Production, 98, pp.328–335.

Paper III introduces a tactical data analysis tool, Looplocal, which has been designed by the authors to support the role of regional IS facilitation. Looplocal is a visualization tool built to assist in 1) simplifying the identification of key regions for new industrial symbiosis facilitation activities 2) enabling proactive and targeted marketing of potential exchanges to key actors in specific regions and 3) assisting facilitators to assess the various strategies and consequential engagement and analysis methodologies suitable for additional IS development in specific regions. The tool analyzes industrial symbiosis case data and estimated regional material and energy flows (on a facility level) along with key industrial geography data to identify potential material transfers. The authors have performed a proof of concept run of this tool on Sweden. In its early stages of application, the method has given results seen as useful for prioritizing regions for the allocation of symbiosis facilitators' resources. The tactical tool shows potential for potential facilitators such as waste management companies or national/regional authorities. Further research will need to be conducted to examine the value and validity of tool in broader development routines.

Methods of Paper III

Paper III took a design approach to study data analysis support for IS development. In this study the data analysis tool “Looplocal” was designed, developed, and proofed. This tool employs material flow data from Life Cycle Inventories (LCI), industrial waste production data, data on the industrial geography of Sweden (classification and location), industrial economic data, and data from successful IS cases. These data inputs are shown as D1 and D2 in Figure 3-3. The data is consequently integrated and presented via allocation (P2)¹⁵, standardization (P3), matching (P4), and visualization (P5) summarized in process flow below.

Figure 3-3 The process flow of the Looplocal tool

¹⁵ P2 is an application of heuristic Material Flows Accounting (MFA) where the flows of input and output materials to and from industries in regions were calculated from D1 data.

Paper IV

Davis, C., Aid, G. & Zhu, B., 2017. Secondary Resources in the Bio-Based Economy: A Computer Assisted Survey of Value Pathways in Academic Literature. Submitted to Waste and Biomass Valorization.

The study described in Paper IV aimed to explore how machine assisted information processing might assist in analyzing large bodies of text to distill and elicit secondary value pathways. The study employed multiple methods (literature collection, Topic Modelling, and Co-occurrence Mapping of entities) on a collection of 53,292 articles from academia in the general area of *Technologies, Applications, and Products* (TAPs)¹⁶ for bio-based wastes. The Topic Modelling presented an overview of 50 clusters of research around secondary organic resources, processes, and disciplines. The Co-occurrence Mapping results combined with interactive exploration tools allow an analyst to understand which TAPS are researched in relation to a broad spectrum of organic resources. Using detailed dictionaries of organic wastes and TAPs, the co-occurrence method mapped out 7,118 unique intersections between 473 specific wastes and 228 TAPs. The developed tools showed good potential when tested by students and academics. However, as with Looplocal, the approach has yet to be fully evaluated in broader WM development frameworks. Nevertheless, this work points the way to setting up a tactical identification systems that can be used to suggest novel pathways for organizations to work toward creating higher value in the Circular Economy.

¹⁶ TAPs represent Technologies, Applications and Products - e.g. incineration: Technology, organic farming: Application, succinic acid: Product.

Methods of Paper IV

Paper IV utilized data collection and data analysis methods. In approaching this study, data (abstracts, authors, keywords) from 53,292 academic papers (containing key terms such as ‘waste’, ‘process’, and ‘organic’¹⁷) published between 1995 and 2014 was collected from Scopus and Web of Science. Subsequently, Topic Modelling and Co-occurrence Analysis of entities was performed on this dataset.

Topic Modelling was employed to distinguish the prominent topics in the collected dataset. It short, it provided an interactive summary of what had been collected. This summary allowed the authors to improve the collection of abstracts by quickly scanning to see if expected topics were included and subsequently refine the search. The particular algorithm used for the Topic Modelling analysis was Latent Dirichlet Allocation (LDA) (Blei et al. 2003), using the MACHine Learning for Language Toolkit (MALLET) (McCallum 2002) software. Results of this analysis were visualized using with the dfr-browser library for R.

Co-occurrence Analysis was performed to examine in more depth the content of the data, and to begin to identify a broad range of processes utilized for waste material valuation. This process analyzed and visualized which types of wastes were mentioned in the literature along with certain types of TAPs associated with the bio-based economy pyramid (see Figure 2 in Paper IV). More detail into the construction of, and results from, this method can be found in Paper IV and interactively on Davis & Aid (2016)¹⁸.

¹⁷ For example the Scopus search terms were “TITLE-ABS-KEY (*technology* OR *process* OR *conversion* OR *treatment*) AND TITLE-ABS-KEY (*waste* OR *by-product* OR *byproduct*) AND TITLE-ABS-KEY (*organic* OR *bio* OR *biodegradable*) AND NOT TITLE-ABS-KEY (*rankine* OR *desalination*)”

¹⁸ <https://is.gd/wastecircle>.

Paper V

Aid, G. & Brandt, N., 2012. Improvement of aggregate cycles in Stockholm and the Baltic Region Activities and results of the BRA initiative. In WASCON 2012 - towards effective, durable and sustainable production and use of alternative materials in construction. Gothenburg, Sweden.

Between 2009 and 2012 project BRA (Bygg-och Rivningsavfall i Stockholms Län) “*Construction and Demolition (C&D) waste in Stockholm County*” was coordinated by the author. This project focused on actively improving (from plural perspectives) the cycles of C&D (specifically non-metallic, inert) materials in the region. In examining inter-organizational collaboration tactics, a highly participative action research procedure was adopted for the project. Methods such as collective system definition, collective goals setting, and action planning- were applied within a series of workshops, focus groups, and symposiums. Several issues (such as market immaturity, 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 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. In evaluating the process and methods during and after the project, participants found the activities of collective goal setting, creating-measuring-and planning after indicators, and face-to-face interaction some of the most effective methods for inter-organizational collaboration toward addressing broad system problems.

Methods of Paper V

Paper V utilized a variety of collaboration methods and systems' analysis methods within an engagement process. To study collaboration tactics for inter-organizational initiatives, a collaborative project was organized with the aim of making secondary C&D resource management more effective in the Stockholm region. Representatives from material suppliers, Building Information Modelling (BIM) system managers, architects, city planners, construction companies, logistics companies, WM companies, the Swedish environmental agency, national and international sector organizations, and specialized consultancies were brought together in a series of workshops and symposia.

The general principles and a broad array of methods from the Action Research discipline (Reason & Bradbury 2007) and Soft Systems methodology (Checkland 1999) were employed in the project. The action research cycle (plan, do, study, act) (Susman 1983; Hopkins 2008), the concept of progressively focusing in (Aid 2013), and the reflective process (Schön & Rein 1995), were the three general principles applied. These principles formed the structure of the collaboration in general, and within the individual collaboration activities (e.g. individual workshops).

Focus groups, rich pictures (Open University 2016), the CATWOE process¹⁹, voting (Dick 1997), and collaborative indicator creation and analysis (Bell & Morse 2008) were among the key collaborative methods used within the first four workshops. Furthermore, *MFA* was applied to gain a better understanding of the flow of secondary inert material in the Stockholm region, and when measuring selected indicators for the project²⁰. For a comprehensive overview of the applied methods see Tables 1 & 2 of Paper V and Aid (2013).

Paper V utilized a range of semi-structured interviews to better understand the state of the system of study - its drivers, stakeholders, and key interrelations. Additional interviews were used to compliment group activities to define and verify priority problem areas, to reflect upon and evaluate the process (during its multiple stages), and to review the results of specific inter-organizational collaboration and planning methods.

¹⁹ CATWOE stands for Customers, Actors, Transformation processes, World view, Owner, and Environmental constraints. The process was designed to assist in group brainstorming around systems' based issues (Checkland 1999).

²⁰ This MFA work laid the groundwork for subsequent Life Cycle Analysis performed within the project (Juhl 2014)

Figure 3-4 gives an overall timeline of the research project further described in Paper V and Aid (2013) - from initial analysis and interviews in 2009 through several workshops (WS#) and a coordinated course to international symposiums and conferences (co-coordinated with the SIMM- CCITIES project).

Figure 3-4 A timeline of the activities related to the C&D project detailed in Paper V

CHAPTER FOUR

4 RESULTS

The summary of results of the studies is structured after the two main research questions— roles and tactics. Chapter 4.1 begins by giving an overall review of the key findings in the studies. Chapters 4.2- 4.5 look closer at the identified roles in the studies. Special attention is given to the anticipated capacities of WM organizations to overcome barriers to these roles (Chapter 4.3) and fulfill potential activities of these roles (Chapter 4.4). In concluding the presentation of results regarding roles, a summary of opportunities, risks, and key enabling factors identified in the studies is provided (Chapter 4.5).

Entering the second research question, Chapter 0 gives an overview of tactics identified and explored in the studies. Two specific tactical areas, data analysis and collaboration, were studied in more depth for Papers III-V. Chapters 4.7 and 4.8 summarize the key findings of these tactical studies respectively.

4.1 KEY FINDINGS OF THE STUDIES

Of the five studies that are included in this thesis, two focus on novel roles available for WM organizations to assist in moving toward more effective and efficient resource management. These studies do not map out a comprehensive list of possible new roles for WM, but took inspiration from two specific tenets of the IE field of study²¹. Four specific roles have been identified and examined focusing on WM organizations' capacities, role opportunities, role risks, and key enablers. These roles are regional IS facilitator, eco-industrial park manager, holistic facility management provider, and high value resource extraction operator.

Representatives of WM organizations in Sweden do see that their companies have many capacities to fulfill such novel roles. However, depending on the role, extra resources will need to be put into developing new capacities such as: co-location recruiting, utilities provision, collaboration coordination, cleaner production facilitation, symbiotic matching, or facility management activities (e.g. dual-flow management). The main opportunities identified for these roles are staying ahead of market developments, access to materials and new markets, and effectively aligning activities with organizational visions (such as reducing waste, decontaminating the environment, or providing critical materials to society). The main risks associated with these roles are insufficient returns on investment, volatile markets, and uncertain future regulatory conditions. Looking forward, the main enablers identified are: policy leadership for more balanced market mechanisms, increasing organizational abilities to take advantage of external knowledge, developing long-term partnerships, stockpiling resources, and carefully crafting new business models.

These key enablers have been unpacked alongside business development and IE literature in identifying seven general tactical areas with potential to support novel roles. Two of these areas: collaboration tactics and data analysis to support external knowledge use, have been investigated in Papers III, IV, and V. In regards to data analysis, these studies developed unique approaches to supplying insight into industrial regions and waste valuation pathways. While these tools work as proofs of concepts which provide many results in themselves, their integration into broader organizational activities are key to their success. The study into collaboration tactics found that collective goal setting, collective system clarification, indicator setting, and iterative in-person processes are key to tactical success. The next two sections present in more detail the findings related to RQ1 and RQ2.

²¹ These two tenets being: fostering inter-organizational cooperation for circular waste valuation and the conservation of resources used for production.

4.2 NOVEL ROLES FOR WM ORGANIZATIONS

The studies explore two general role areas for WM: inter-organizational resource management and high value resource extraction. In Paper I, the general inter-organizational area has been unpacked to three unique roles: *regional IS facilitator*²², *eco-industrial park manager*, and *holistic facility management*. Paper II further considers the role of *high value resource extraction*. These four roles are briefly introduced in the following pages. Subsequently, the four roles are summarized and compared side-by-side with traditional WM activities in Table 4-1.

Regional IS Facilitator

Facilitated IS regions have key coordinators actively looking to identify and assist in developing IS linkages (Baas & Boons 2004; Mirata 2004; Hewes & Lyons 2008). In contrast to Eco-industrial parks, less focus is on co-location and recruiting new businesses, allowing for further inclusion of established and geographically disperse organizations within a region. The Swedish WM company Econova is currently approaching the role of IS facilitator by initially pursuing an enhanced understanding of the industrial geography and industrial metabolism of their target regions (Econova 2016; Gravert & Mattsson 2016). Such surveying activities are intended to assist in the identification and evaluation of potential inter-organizational efficiency measures. However, as underlined by a representative of this organization, fulfilling the role of regional IS facilitator has a lot to do with bringing individuals and firms together to develop symbiotic regional networks.

²² The role of Regional IS facilitator was not directly identified from the interviews in Paper I, but via the literature review for Paper I

Holistic Facility Management

A relatively new area that private actors interviewed in Paper I are entering is that of facility management, where the WM organization embeds itself further into the running of customer facility functions such as material procurement, on site waste management, and environmental reporting. Kincaid (1994) gives a detailed list of potential activities for, and key characteristics of, facility management. This approach is seen as an entry into identifying cleaner production solutions alongside innovative waste management pathways for multiple materials on site and regionally. The respondents in Paper I stressed that in order for long term innovation and continuous improvement to be effective, fixed prices (focused on how activities are to be performed) should be avoided and instead goal oriented²³ pricing such as those in Vested outsourcing (Vitasek & Manrodt 2012) would be beneficial.

Eco-Industrial (Symbiosis) Park Manager

An eco-industrial park is a community of businesses pursuing to improve their collective economic and environmental value creation through collaborative resource (energy and material) management (Lowe 1997; Côté & Cohen-Rosenthal 1998; Erkman 2001). Often there are coordinating organizations that engage and recruit external organizations seen as potentially symbiotic with other organizations in the park (Gibbs & Deutz 2007; Chertow & Ehrenfeld 2012). In addition to such activities, the role of Eco-industrial park manager, could include utilizing varying degrees and combinations of the barrier removal capacities identified in the interviews, such as environmental permit knowledge, secondary market experience, technical knowledge, buffer capacity etc.

One private and one public WM organization included in the study for Paper I have plans to build up eco-industrial parks co-located with their WM facilities. NSR, a public WM organization in the south of Sweden has started their transition to being a symbiosis park manager, and currently hosts dozens of diverse organizations on or next to their core facilities. This was achieved by both outsourcing many of the operations that were previously performed in-house, but also by establishing an on-site business incubator, and actively looking for new industries suitable for the various undervalued material and energy streams in the area. A detailed description of their activities in this area is given in a Waste Sweden (2014b) report.

²³ E.g. amount of costs saved, % waste reduced, jobs created, etc.

High Value Resource Extraction

Extraction of specific substances and materials from waste is considered functional recycling when the full (initial) function of a material is retained and utilized in its next use (Graedel et al. 2011). Over long periods, functional recycling eases the economic viability of cycling of high value materials through several iterative use cycles by slowing the entropy of resources, as opposed to dispersing these valuable resources into high volume low value recycled products such as road base. When resources are functionally recycled, virgin materials (and the wastes associated with the extraction and production of these virgin materials) are substituted. In the case of copper this means preventing up to 500 tons of upstream waste and materials by extracting and recycling one ton of copper (per cycle) (Schmidt-Bleek 1999). For phosphor, the ratio is estimated to be 1 to 50 (Van Kauwenbergh 2010). While the WM sector has performed functional recycling of some materials (such as Au and Al) to some degree, the role is still in development and often suffers from unfavorable market mechanisms.

Table 4-1 A comparison of the traditional WM role to the novel roles taken up in this study
Italics demark relatively novel activities for WM providers

	Role	Geographic Scope	Potential Services to Customer	Products
	Traditional WM	upstream: regional to national, downstream: regional to international	collection, landfilling, sorting, stabilization, de-contamination, trading	Traditional recycled materials (plastics, metals, paper, construction material etc.), recovered fuels
Paper I	Regional IS Facilitator	Municipality, several municipalities	<i>matching, collaboration coordination, support services, knowledge exchange, innovation support, lobbying for the region & concept ...</i>	Potential to deliver recycled products (traditional or extracted secondary) to the customer as add on service from other roles
	Eco-Industrial Park Manager	Medium (in Sweden), large parks exist in other countries	<i>recruiting, resource matching, utilities, lobbying for the park, environmental monitoring, cleaner production audits, environmental training, innovation support, other support services ...</i>	Potential to deliver recycled products (traditional or extracted secondary) to the customer as add on service from other roles
	Holistic Facility Management	Small	<i>Dual flow management, procurement, environmental monitoring, cleaner production audits/ development, co-innovation, training, maintenance ...</i>	Potential to deliver recycled products (traditional or extracted secondary) to the customer as add on service from other roles
Paper II	High Value Resource Extraction / Functional Recycling	upstream: regional to national, downstream: national to international	collection, sorting, de-contamination ...	<i>High value secondary materials</i> (e.g. plant available P, or clean Cu from ashes) which directly substitute virgin material functionality

Looking at the comparisons in Table 4-1, it becomes clear that the inter-organizational resource management roles of IS facilitator, eco-industrial park manager, and holistic facility management are quite distinctive in regards to the offerings of traditional WM. Such novel roles would require the development of several new services (*noted in italics*) is an organization does not already include such offerings in their portfolio. On the other hand, high value resource extraction most closely resembles the services and products of traditional WM. However, this novel extraction role takes a more focused approach toward

the specific extraction of resources (e.g. P & Cu from ashes) to substitute the functions of valuable virgin materials²⁴.

If the leadership of a WM organization chose to enter any of the new roles, it is likely that they would choose a combination of several roles (e.g. IS facilitator together with traditional WM). In such a fashion, the roles of traditional WM and high value resource extraction might benefit from gaining access to upstream materials and downstream markets via service focused roles. In fact, WM organizations already do this to some extent today, offering certain services (e.g. facility management) to improve and secure material flows to recycling operations. If any new role stands to improve resource management effectivity is dependent on the goal toward which effectivity is measured (regional goals, organizational goals, macro social goals, etc.). Further reflection and contextualization of these four roles and their relation to improving effectivity and efficiency is given in the discussion chapter.

4.3 CAPACITIES TO OVERCOME BARRIERS TO INTER-ORGANIZATIONAL ROLES

Paper I addressed the general capacities for WM firms in Sweden to overcome barriers to inter-organizational resource management and innovation in terms of general inter-organizational barriers but not the barriers to the specific roles. However, these results can provide broader worth in eliciting the general capacities which Swedish WM executive believe their organizations can fulfill.

Table 4-2 summarizes the responses of the representatives of Swedish WM to questions regarding how their industry does or could help in overcoming various barriers to IS. While the respondents did not agree on all capacities, they did express that the sector does and can provide many barrier alleviating activities to IS (and in turn inter-organizational) role implementations.

²⁴ For an in-depth exploration of the differences between downgrade recycling and functional recycling see Peck (2003)

Table 4-2 Interviewees' comments on activities which the WM sector does or could perform in relation to barriers for inter-organizational resource management (Paper I)

Category	Barrier	Existing Assistance Capacity
Economic	High investment costs	Raise access to capital together*
	Long ROI	Sharing of CAPEX costs*
	Unclear division of income and costs	Clarify division through innovative contracting models
	Uncertain margins	Assist with internal WM market knowledge*
	Instable market (unsure market)	Provide a network buffer & base of market experience
Social	Aversion or reluctance to change	Support the change by letting partners focus on core business
	Social isolation	Bridge to the wider WM sector networks
	Lack of engagement, priorities, and time	Allow partners to focus on core while WM sector acts as engagement center
	Lack of trust, Resistance to many external actors	Act as a single trusted contractor, use of innovative contracts to reduce risk
	Aversion to collaboration and dependencies	Act as the one main contact point
Technological	Technical solutions not on commercial scale	Experience and framework for development of new solutions
	Material is unsuitable for reuse	Ability to add intermediate processes or stockpile
	Lack of technical knowledge	Large base of technical knowledge in the sector
	Quality assurance demands	Ability to provide quality assurance offerings
	Quantity demands	Buffer material / stockpile material / several material sources
	In time delivery demands	Logistics solutions such as in time delivery
Information Related	Administrative requirements	Long term competency in the area
	Limited knowledge about the market	Internal business intelligence systems in the sector on material flows
Policy related	Require permits	Permits in place, and experts in applying for new permits
	Unsure legislation	Knowledge of complex regulation, lobbying capacity

*= an asterisk denotes that some of the organizations studied were not involved in the activity and/or the representatives did not see these activities as being a strong possibility for their company moving forward.

4.4 CAPACITIES TO PERFORM NEW ROLES

It is unlikely that all WM organizations are presently well equipped to perform some of the activities listed in Table 4-1 (summary of the role activities), such as recruiting to Eco-industrial parks, utilities provision, collaboration coordination, cleaner production facilitation, or novel facility management activities (such as dual-flow management). Table 4-3 lays out the major activities of the four identified roles (from Table 4-1) side-by-side with the interviewee expressed capacities of Swedish WM organizations (from Table 4-2).

Table 4-3 Expressed capacities of Swedish WM organizations in relation to key activities of the four novel roles

Role	Potential Service/ Product Activities	Expressed Capacities Related to Specific Roles ²⁵
Regional IS Facilitator	matching, collaboration coordination, support services, knowledge exchange, lobbying	waste market knowledge, broad inter-sectoral network, technical ability, lobbying capacity
Eco-industrial Park Management	recruiting, matching, utilities, support services, lobbying	waste handling/upgrading knowledge, waste market knowledge, technical ability, lobbying capacity, permit knowledge
Holistic Facility Management	dual flow management (materials in and out), procurement, cleaner production development, co-innovation	waste market knowledge, technical expertise, distributed sourcing, regulatory expertise, expertise allowing partners to focus on core business, ability for warehousing/stockpiling and in-time deliveries
High Value Resource Extraction	collection and reporting for upstream customers, producing high value secondary raw materials for downstream customers	material flow knowledge, technical ability, lobbying capacity, short term buffer capacity, permits, access to disperse upstream sources

Depending on the WM company, minor to major investments will be needed to roll out novel roles in their selected forms. This depends on the specific capacities of a WM organization (e.g. key competencies, current offerings, and infrastructure) and the ambition they hold for new offerings. As such, clarifying the opportunities, risks, and key enabling factors of potential new offerings in relation to their required additional investment will be an important activity.

²⁵ These capacities are by no means certain for all WM companies, but they are capacities with high potential as identified in the studies.

4.5 OPPORTUNITIES, RISKS, AND KEY ENABLING FACTORS

In looking to clarify potential opportunities, risks and key enabling factors for novel roles; expert interviews (Paper I in relation to inter-organizational roles) and literature review with scenario comparisons (Paper II in relation to high value resource extraction) were employed in the studies. Table 4-4 summarizes opportunities, risks and key enabling factors detailed in the respective papers.

Table 4-4 Opportunities, risks, and key enabling factors for the two general roles

Inter-organizational Resource Management	High Value Resource Extraction

Opportunities	
<ul style="list-style-type: none">• New business markets• Not being left behind in market developments<ul style="list-style-type: none">• Access to higher value resources• Potential to align conflicting internal goals<ul style="list-style-type: none">• Enhanced sustainability profiles• Develop more attractive and competitive industrial regions• Align operations more closely to circular visions	<ul style="list-style-type: none">• Reduce probability of costly remediation in the future resulting from risky alternative material pathways• Enable decontamination alongside recycling• Potential to increase in profitability as compared to alternative management pathways<ul style="list-style-type: none">• Provide resources deemed critical by society, authorities, and customers• Align operations more closely to circular visions
Risks	
<ul style="list-style-type: none">• Cut out of benefits of development investments• Potential loss of supply contract resulting in no return on investment• Potential of having to pay for remediation activities under new regulation	<ul style="list-style-type: none">• Difficult to stay competitive and profitable with current market conditions• Fast changes in market prices for high value resources could drastically reduce profitability of long term investments and activities (such as stockpiling)• New or higher taxes for disposing of extraction by-products reduce profitability potential
Key Enabling Factors	
<ul style="list-style-type: none">• Long term partnerships• Balancing market mechanisms for secondary materials / Policy leadership<ul style="list-style-type: none">• New business models• Utilizing knowledge and innovation	<ul style="list-style-type: none">• Enabling the potential to stockpile• Balancing market mechanisms for secondary materials / Policy leadership<ul style="list-style-type: none">• Low costs for by-product management• Lower economic viability for alternative pathways for wastes• Improved forecasting of future regulation and markets

4.6 TACTICS TO SUPPORT NOVEL ROLES

Once a WM organization has the organizational will, capacities (or plans to build capacities), and has begun to put together broader business models for novel roles – it will be useful to look at operations or implementation practices that can be employed to maximize value and revenue creation within these models. The second research question focuses on support tactics for WM organizations in approaching new circular roles, in particular the tactics for value-chain development and data analysis for information support. During the interviews in Paper I, *long-term partnerships* were lifted by the interviewees as a key enabling (tactical) areas often developing out of *value chain collaboration*. The interviewees also highlighted the activities of *policy leadership* (tactical lobbying), *the use of external knowledge/ data*, and *new business models* as key support activities for the discussed roles. Paper II also highlights the importance of *policy leadership* and brought up the possibility of *stockpiling* as a unique supporting tactic for high value resource extraction. Figure 4-1 illustrates how these tactical areas could support the two general roles of this thesis. The main tactical areas studied in this thesis have bold outlines. A tactic may be supportive of other tactics (e.g. using external data intelligence to support product and service innovation tactics). As illustrated, some of the discussed tactics may be valuable for more than one role. Two of the tactic areas (white boxes in Figure 4-1) have been explored via separate studies, e.g. use of data analysis in Papers III & IV, and collaboration tactics in Paper V. The remainder of this chapter reviews the key findings of these studies.

Figure 4-1 Tactical areas identified within the thesis and their potential to support studied roles

4.7 DATA ANALYSIS TACTICS

In sectors other than WM, data analysis and informatics play a large role in the development of business intelligence, including the collection and extraction of e.g. market and technology information (Dayal et al. 2009). Currently, Swedish WM primarily uses data analytics and informatic tools such as geographic information systems (GIS) and customer relations management (CRM) for process support (Staf 2014). Papers III and IV were *design-oriented* studies that sought to develop and evaluate new methods for making use of a growing amount of available market, technology, valuation, and resource flow information. These proof of concept studies show that the use of diverse information from academia, statistic bureaus, environmental agencies, and internal material flow databases can be analyzed together to give new insight into regions for IS Facilitation (Paper III) and emerging value pathways for waste organic materials (Paper IV). Examples of analysis output from these tools built to support novel roles are shown in Figure 4-2.

Figure 4-2 Graphical and interactive interfaces to support data analysis for new roles

Specifically, the tools can combine and analyze broad sets of structured and unstructured information, giving approaches to make sense and use of large collections of public and proprietary information. These studies have shown that new approaches to applying such information can significantly reduce the manual efforts required toward compiling information. However, while the tools show good potential for achieving their individual aims, and have been evaluated by various user groups (academics, students, WM professionals); they will require further evaluation in line with the specific activities targeted by WM organizations within novel roles. Such contextual issues regarding data analysis tools are further expanded upon in the discussion.

4.8 VALUE CHAIN COLLABORATION TACTICS

The multi-year project described in Paper V, and further in Aid (2013), was an extensive study generating many results in regards to the various objectives, methods, and procedures of the C&D focused project. A few key results can be lifted from the insight gained in follow-up interviews to the project. Specifically, participants in the project (throughout its various workshops, symposia etc.) expressed that the methods used in *clarifying the complex system*, *establishing physical meetings to build trust*, *setting collective goals*, and *establishing an indicator system to follow up on collective goals* were some of the most important activities in enabling collaboration for change and innovation. See Table 4-5 for a summary of the methods connected to these activities.

Table 4-5 Key collaboration enabling activities highlighted by participants of the C&D project

Key support activities highlighted by participants	Methods used to support these activities	References for the methods
Clarifying the complex system (Collective systems view)	CATWOE ²⁶ , Rich Pictures	(Checkland 1999; Adamides et al. 2008; Open University 2016)
Setting collective goals	Focus Groups, Voting	(Morgan 1996; Dick 1997; Dick 1998)
Building trust via inter-sector meetings	Workshops, Symposia	(Reason & Bradbury 2007)
Establishing an indicator system to follow up on key goals	DPSIR Framework	(Bell & Morse 2008)

The overall approaches to collectively defining the system, as well as priority areas and problems (utilizing rich pictures and CATWOE), allowed for problems that were important to key stakeholders to be addressed accordingly, and in turn novel solutions to arise such

²⁶ CATWOE stands for Customers, Actors, Transformation processes, World view, Owner, and Environmental constraints. The process was designed to assist in group brainstorming around systems’ based issues

as the planning checklist and regional medium-term storage hubs. Consequently, the participants noted that there was a good amount of stakeholder buy-in to both the analysis and the action processes as exemplified by the efforts to begin a new cross-sector industry organization and the initiatives to collectively apply for European development financing. However, such approaches do require large outlays of human resources. The findings from this study in relation to the broader thesis and key issues (such as time requirements) are reflected upon and discussed in the next chapter.

CHAPTER FIVE

5 DISCUSSION AND REFLECTION

This chapter begins in sections 5.1 and 5.2 by examining how the findings are situated in relation to other scholarly work, what the findings may contribute to the fields of IE and Business Development, and how the results may support IE aligned business roles. This discussion is followed by a detailed examination of the implications of aiming for 'efficiency' and 'effectivity' in resource management roles. A reflection on the overall normative and pragmatic research approach of the work is provided before the chapter is closed with a presentation of areas for further research.

5.1 APPROACHING NOVEL ROLES

This section begins by broadly by addressing the various development pathways (and in turn research potentials) for the studied roles. Subsequently, a deeper examination of the IE and business development context of the four roles is given respectively.

From a business development perspective, ‘internal development’²⁷ has been the main tactical approach studied for the four roles identified in this thesis. Taking a step back, internal development is not the only option for operationalizing new roles. A beneficial approach to discussing and analyzing the potential business roles is through the Familiarity Matrix shown in Figure 5-1 (Roberts & Berry 1985). Researchers in the field of business development and innovation state that new development activities situated at the bottom left of the matrix have a better chance of success (Roberts 1992), however developments toward the top right have more potential for increased earnings (Lai et al. 2006; Pohle & Chapman 2006). Furthermore, unfamiliar markets, products, or services may require a development strategy which makes use of venture capital, acquisitions, joint ventures, educational acquisitions²⁸, or strategic partnerships (Roberts 1992). Looking back at Table 4-1, for most Swedish WM companies (even with relatively good market knowledge), the new services of the three inter-organizational resource management roles will situate themselves further toward the right with decreasing knowledge of the service. Therefore, some of the enabling tactics identified in the studies (such as strategic partnerships, new business models and value-chain collaboration) may be of assistance in further studying new resource management developments and ventures.

²⁷ The ‘make’ in the industry termed ‘make/buy’ decision

²⁸ Educational acquisitions are acquisitions aiming to build a base of core staff in a new area, not for the sake of market positioning.

Figure 5-1 The Familiarity Matrix (in bold) from Roberts & Berry (1985) with strategies for business development (in italics) as laid out by Roberts (1992)

It is important to note that just because WM industries see themselves as having the capacities (or as willing to acquire necessary capacities) to fulfill activities within unfamiliar roles, it does not mean they will want to, or will be able to make the transition. As poignantly put by Sniukas (2012, p.13) many managers and employees of companies see business as usual as “the dominant logic of ‘how things are done around here’, how value is traditionally being created and captured is hard to break.” Furthermore, in considering the development of any new role, a WM organization should consider factors such as: how much of their existing business will be cannibalized²⁹ by the new role, if the new approach will balance out lost revenue from cannibalization, and if the role will help the organization to effectively achieve its strategy and vision (Nijssen et al. 2006).

²⁹ For example, the loss of landfilling or recycling income due to cleaner production services.

Regional IS Facilitator

The studies showed that Swedish WM organizations have some key capacities related to regional IS facilitation, such as waste market knowledge and technical ability. Additional studies around IS facilitation provide a strong backdrop for researching how WM organizations may further develop the role of regional IS facilitator. For example, the bringing-together and communicative function of IS facilitators has been stressed by several researchers in the field (Mirata 2004; Costa & Ferrão 2010; Spekkink 2016). Bringing-together activities not only involve engaging regional industries in discussion around resources, but also include organizing focused meetings, bringing in external experts to address regional representatives, facilitating communication with policymakers, arranging study tours, etc. (Mirata 2004). Therefore, in studying tactics to support the role of IS facilitator, researching approaches for inter-organizational collaboration should be instrumental.

Interestingly, the barriers to implementing IS (technological, economic, social, information) outlined in Paper I, are extremely similar to those identified in the inter-organizational innovation literature. See for example Table 4 of Jalonon (2012) which summarizes the factors for uncertainty and their manifestations in innovation processes. This uncanny similarity, strengthens the groundwork of Paper I, and can in-part be accounted for if one views IS facilitation as ‘green’/resource efficiency driven variety of inter-organizational innovation. Additional barriers identified in the innovation field include ‘legitimacy uncertainty’ (if an innovation is inconsistent with an individual’s or organization’s norms and ‘world view’), ‘timing uncertainty’, and ‘consequence uncertainty’. Further studies into barriers and enablers for operationalizing IS roles should benefit through further analysis and incorporation of the findings and approaches of inter-organizational innovation.

Eco Industrial Park Manager

The studies showed that WM companies have unique capacities that can benefit eco-industrial parks, such as waste treatment expertise, permit knowledge, waste market knowledge, etc. Indeed, WM companies are tenants of several eco-industrial parks around the world (Massard et al. 2014). However, in studying approaches for WM organizations to perform the role of eco-industrial park managers, there are a multitude of novel (to WM) services that could be considered³⁰. One suggestion from the business development literature is for an organization to start small, work with what the company knows, and

³⁰ See page 101 of P.J. Mol and Joost C.L. Van Buuren (2003) for an extensive list of potential park services.

slowly grow from there (Roberts 1992). This approach has been seen in the IE literature. For example, one WM company, Heros in Holland, approached the task of eco-industrial park developer when they had surplus terrain on an industrial site they had acquired (Spekkink 2016). Heros actively recruited industries which could make use of their wastewater and solid waste treatment capacities. In recent years, other industries have established themselves nearby, such as warmCO₂ (a process supplier for waste CO₂ and heat utilization), and a greenhouse complex.

As with regional IS facilitation, the importance of the social aspects (Hewes & Lyons 2008) and proactive political communication (Gibbs & Deutz 2007) of eco-industrial park champions has been lifted by IE scholars. Here again, most WM companies not familiar with the activities and processes necessary to serve as a successful landlord or utility provider will need to explore their options for building capacity, bringing in capacity, or partnering.

Holistic Facility Management

Holistic facility management is “the integrated management of the workplace to enhance the performance of the organization” (Tay & Ooi 2001). In such a role a provider can carry out a diversity of activities such as maintenance, procurement, cleaner production audits, and energy and waste management (Meneghetti & Nardin 2012). The studies in this thesis found that WM organizations may hold specific capacities for performing this role, such as distributed sourcing, ability for warehousing, waste market knowledge, etc.

While this role is facility focused, by integrating a WM organization into activities such as dual flow material (procurement plus waste management) and energy management, regional oriented efficiency measures can be established via e.g. material matching and value-chain development. In countries, such as Sweden, where industry is geographically disperse, performing such a role can be seen by a WM organization as an alternative or complement to regional IS facilitation.

Holistic facility management is not a theme common to IE, however there is much work in the field surrounding cleaner production, sustainable manufacturing, and value chain innovation. (van Berkel et al. 1997b; Despeisse et al. 2012). If a WM company looks to provide procurement and cleaner production services some potentials identified in the IE literature include designing products and process to use less, shifting to biologically inspired production models, and moving from toxic and non-renewables to non-toxic and renewable materials (Graedel & Howard-Grenville 2005; Abdul Rashid et al. 2008; Seliger

et al. 2008; Despeisse et al. 2012). Outside of IE, research in the emerging niche of Sustainable Facilities Management can help in further studying how WM organizations might assist with facility aspects such as energy and emissions performance measures and green building design and evaluation (Nielsen et al. 2016).

High Value Resource Extraction

While, the most similar to traditional waste management activities, the study performed in Paper II highlighted regulatory and market factors such as changing Swedish limit levels (and in turn future risks) over time³¹, the forecasted criticality and price development of extracted materials, achieving economies of scale, and the value of alternative waste pathways as critical in enabling this role. Other researchers in the field of IE have found comparable enabling factors (market price, alternative cost, economies of scale) for similar activities such as extracting resources from landfills (Peck 2003; Johansson et al. 2016) and industrial wastes (Andrews 2002). Additional factors identified in the field which can impact the viability of resource extraction roles are heterogeneity and functionality of the extracted resources (Johansson et al. 2016) and institutional capacity (via e.g. the EPA) to support ‘mining’ activities by the WM branch (Johansson 2016).

Looking internally, WM organizations would need to evaluate their current decision making, price settings, and development routines from a total value chain perspective (upstream collection to processing to downstream secondary markets)³². Adjustments might need to be made to consider longer time perspectives, new tactics for market prognoses and evaluate market drivers, and even new ways of collaborating with up and downstream partners (as process industries do). Noted in Paper II, supporting tactics of interest for further study would be tactical lobbying (balancing the playing field and pushing for institutional capacity building) and stockpiling. In the next section, we discuss some of the tactics identified in the studies that could support WM organizations wishing to pursue such roles.

³¹ See another article by the author (Kihl & Aid 2012) for more details on this aspect.

³² Inspiration could be taken from Lager & Storm (2013).

5.2 APPROACHING TACTICS FOR THE ROLES

As shown in Figure 4-1, there are many potential tactical areas for scholars and WM organizations to investigate and invest in to support resource management roles. This discussion section focuses on six of these areas, reflecting on how this study and other studies from IE and Business Development might assist in increasing value for new roles.

Developing New Business Models

Given the innovative nature of perusing new services and products, the creation of new business models can be seen as a tactic for organizations in structuring the logic behind new or re-packaged offerings³³. For example, if a WM organization decides on a strategy to “*create the world’s most resource-efficient region*” as Tekniska Verket (2016) has, and identifies e.g. IS facilitation as roll that could fulfill that strategy, a broader business model will need to be developed to further clarify revenue models, distribution channels, customer relations, etc.

Exploring new and adapted ways generate revenues and to define value for up and downstream customers and partners can be a powerful process for incumbent companies (Lager 2016). Many studies show that organizations who routinely evaluate and innovate new business models are more economically successful than organizations that focus solely on product and process development (Lai et al. 2006; Pohle & Chapman 2006). Unfortunately, incumbent (as opposed to start-up) companies often lack the internal characteristics which promote business model innovation such as flat hierarchies, support systems for risk taking and change, and decentralized decision making (Sniukas 2012).

Research around business models for circular resource roles is currently an emerging area. In IE, the research surrounding product life extension and product service systems has made great strides in recent years (Walsh 2010; Tukker 2013; Bakker et al. 2014), however there are still relatively few studies exploring the business models for inter-organizational resource management and secondary resource extraction in depth (especially regarding models that do not involve external financing from e.g. grants). A few explorations of the broader business models for IS facilitation and eco-industrial park managers have been performed in conjunction with studies in this thesis by Eidman (2016) and Gravert and Mattsson (2016), still there remains a lot of research in this area to be done.

³³ While business model innovation is questionably a tactic in the traditional sense of *operations or implementation practices employed to maximize value and revenue creation within the chosen business models*, it is taken up in this discussion as a practice to support the operationalization of novel roles. There are several schools of thought around the non-linear progression of business development and innovation (Stampfl 2016), however these discussions are outside the scope and space of the current discourse.

Product and Service Innovation

Active product and service innovation can be a support tactic for organizations who choose to be leaders in rolling out new circular offerings. As illustrated in Chapter 2.3, scholars often break up product and service development into a multitude of stages within a development progression (Cooper 1986; Ernst et al. 2010). Grant et al. (2010) identified a simplified set of stages for inter-organizational resource management development which includes identification, assessment, development, barrier removal, and commercialization. Table 5-1 assesses how certain approaches explored in the appended papers relate to the first four development stages. From this review, it is interesting to note that the assessment tools and information technology tools applied in Papers III-V situate themselves in the early stages of bringing a new product or service to market. The closer one comes to market (e.g. product or service development, barrier removal, and commercialization phases) other enabling approaches were explored in the thesis, e.g. activities for inter-firm coordination, and potential for policy leadership to impact market drivers.

Table 5-1 Activities within the papers in relation to the phases of bringing a new resource management offering to market

Paper	Identification	Assessment	Development	Barrier Removal
I				Identify barriers, seek capacities and approaches (e.g. policy leadership)
II		Economic assessment, risk assessment		
III	Data analysis to identify key regions / technologies			
IV	Text Analysis to Identify novel technologies			
V	Focus Groups to identify potentials	Indicators to assess potential of identified activities/technologies	Demonstrations of new technologies	Courses to remove certification barriers

Collaboration Tactics

Inter-organizational collaboration is often a key enabling tactic lifted by scholars as lubricants for implementing inter-organizational resource efficiency measures (Mirata 2005; Walls & Paquin 2015). Often the main rationale for this tactic is the expectation of increased economic benefit (Lambert & Boons 2002). Fiedler and Deegan (2007) have looked deeper into incentives for inter-organizational collaboration and subsequently outlined several rationales:

- To increase the firm's competitiveness
- To procure scarce resources, or key resources for a competitive advantage
- In response to external pressures (from e.g. government administration)
- To gain legitimacy amongst their peers or to satisfy the expectations of shareholders
- To create a desired power shift toward allied organizations
- To reduce costs³⁴

Several more rationales, such as value chain innovation or access to intelligence on competitors, could be added to this list.

Much of the collaboration in Paper V was focused on creating effective benefits for the participants by identifying and implementing new and desired system solutions. Specific tactical tools applied toward this end were, system framing methods (rich pictures, CATWOE), collective goal methods (focus groups and voting), information sharing methods (workshops, symposiums, demonstrations), and barrier removal activities (e.g. courses and collective lobbying). Other researchers have noted that system framing methods increase the ability of participants to identify with an issue, and in turn improves collaboration partners' ability to mobilize (Lashley & Taylor 2010). Regarding goals, it has been found that the creation of common goals can improve the effectiveness of collaboration considerably (Nidumolu et al. 2014; Hallstedt 2016).

Coordinating such activities often requires a large time investment. WM organizations aspiring to enter collaboration to support the roles of inter-organizational resource manager or secondary resource extraction would not necessarily need to perform the role of coordinator themselves. External support could be sought for coordination; however, the coordinator often has the leverage to set the initial framing of collaborative undertakings.

³⁴ Some of these general rationales are derivative, e.g. reducing costs and increasing competitiveness.

Long Term Partnerships

Collaboration does not have to include a large group of broad value-chain or landscape (e.g. regulatory) stakeholders. A specific form of collaboration, stressed as an important tactic by the interviewees of Paper I, is that of long term partnerships³⁵. In following this key thread, another round of interviews was performed after Paper I with both WM representatives and representatives of a few of their long-term partners (energy and paper industries). This small follow up study focused on the rationale (the why) and activities of such arrangements. The respondents’ rationales for long term partnerships were focused on *securing resources* and *increasing competitiveness*. In particular, the Kraljic Supply Matrix (Kraljic 1983) was mentioned by two of the respondents as a thought model to explain the reasoning behind forming partnerships around scarce, yet high profit, items. In addition to these points, a few new insights behind the partners’ rationale arose such as the desire for *continued development* beyond single projects and the collaborative *sharing of knowledge and fiscal resources* for mutual product or service development. A summary of the interviewees’ responses regarding the rationale for, and activities in, strategic partnerships is given in Table 5-2.

Table 5-2 Activities and reasoning for strategic industry partnerships between the WM sector and the paper and energy sectors in Sweden

Reason for long term partnership	Activities in partnership
Required competence or technology	Sharing of various key market / technology / legislative knowledge
Resource intensive R&D required	Co-financing or secure external financing together, co-development of new technologies, services, and materials
Risk of limited material supply or downstream customer base	Secure upstream materials or downstream customers within the partnership
Desire for more than one-off activities	Iterative and continual development together in priority areas
Potential for collaborative offerings	Develop package solutions and services in partnership (where each partner's core competencies compliment the other's)

Collaborating isn’t the only approach to access and apply knowledge external to a WM organization, in the next section we discuss the potential for looking outward via data analysis and informatics.

³⁵ For a deeper discussion around partnership models for regional resource management in Sweden, the various forms they take, and perceived success factors see Hållstedt (2016).

Data Analysis to Support the Use of External Knowledge

There are many approaches for collecting information on novel technologies and markets. Regarding technologies, there are e.g. industry periodicals, conferences, academic journals, and patent databases. For market information in Sweden there are two branch organizations and specialized market consultancies such as Profu AB and UC Konsult. Therefore, when considering the development of new informatic approaches, WM organizations will need to evaluate what a new tool could offer in relation to alternative options.

The data analysis tools designed in this thesis focused heavily on supporting the initial identification stage of developing new products or services (See Table 5-1). This limited focus on early product and service development phases has been identified as a drawback in some studies (Grant et al. 2010). However, such limitations can be eased by inter-connecting such tools with other tactical tools with their own strengths in specific areas (e.g. scale up or barrier removal). Additionally, data analysis tools have garnered some critique for focusing heavily on connecting materials instead of connecting people, who often hold key tacit information (Grant et al. 2010). To assist with this there are new informatic tools emerging (similar to collaboration tactics) to support open innovation where social connections can be made and tacit knowledge can be exchanged (Brodschii 2011; Glowbal Brain 2016).

Policy Leadership - Tactical Lobbying

The importance of informing authorities on market imbalances, market barriers, and desired policy was highlighted in Papers I, II, and V. The participants in the BRA C&D project believed increased legitimacy and greater access to authorities could be gained via forming coalitions toward the same interest (improving the conditions for C&D recycling). Therefore, collaboration (and partnership) tactics could be considered by WM as a strategic approach to align WM and allied partners' influence focused communication activities toward unified goals.

For high value resource extraction, the economic conditions for bringing raw materials to market (primary vs secondary producers) are a key area identified for concentrated Swedish lobbying efforts³⁶. For inter-organizational resource management roles, efforts could focus on, e.g. establishing IS/eco-industrial parks as a part of regional or national policy regarding

³⁶ See Johansson et al. (2014) for more details regarding these market conditions in Sweden.

innovation, environment, or economy. Research from IE scholars regarding how such policies have developed in various European countries over recent years could be of particular use in to those looking to promote new roles (Costa et al. 2010; Laybourn & Lombardi 2012; Boons et al. 2015). Furthermore, in moving toward the EU's ambitions for a circular economy (EC 2015), additional issues should be assessed by WM such as the function of the waste hierarchy in a society where wastes are truly to be seen as raw materials (Aid et al. 2016).

Stockpiling

Paper II brought up the tactical activity of stockpiling of resource rich wastes (resource banks) to support the role of high value resource extraction. For this role, stockpiling is a potential activity to enable economies of scale, allow for niche technology to develop, and as an alternative to low value cycling activities that risk costly future remediation. To my knowledge, there are currently no deep studies on the economic and environmental impacts of stockpiling of waste in general or of specific waste fractions. Some studies have been performed which highlight the issue of economies of scale as pertinent for WM (Callan & Thomas 2001; Wang et al. 2014). Such studies underscore the fact that economies of scale are dependent on the product or material of focus - making strategic activities of WM even more complex given the total number of materials with which the branch works. If stockpiling is to be approached by a WM organization, researching issues such as regulation (and potential lobbying options), methods for safe and efficient stockpiling, and life cycle comparison to alternatives should prove useful.

5.3 REFLECTIONS ON EFFICIENCY AND EFFECTIVITY IN RESOURCE MANAGEMENT

This thesis seeks to advance the development of knowledge that can contribute toward more *efficient* and *effective* resource management. While the concepts of efficiency and effectivity, introduced in Section 1.2, are implicitly and explicitly addressed in the thesis and articles, a deeper reflection on their respective implications for resource management roles is important. A large part of the studies into roles focuses primarily on improving resource management efficiency by identifying or supporting the development of technologies and systems which can produce goods with less (new) resource requirements³⁷. In choosing a resource conservation focus, assumptions are being made regarding the ability of more efficient technology to solve the sustainability challenges we face in our scientific, industrial, and normative enterprises.

On the other hand, effectivity is measured in regards to entity specific (and often shifting) aims, making it a more complex subject to address. As pointed out in the introduction, my perspective of the problem of resource management today and moving forward is not that of resource use, but that of the up- and down-stream environmental (and resulting human) impacts of resource use, the conflicts arising from resource availability, and social welfare issues connected to resource use. From this perspective, new roles are effective when they contribute to improvement in these areas. Several studies have shown resource cycling is often, however not always, an effective method to reduce a range of environmental impacts (Bjorklund & Finnveden 2005; Sokka et al. 2011). One can infer that resource cycling and efficiency would put less pressure on potential resource conflict areas and improve the ability for more people to have access to basic welfare needs. While there has been progress in studying social impacts of various resource management routes, via e.g. social life cycle assessment (Aparcana & Salhofer 2013; Umair et al. 2015), there is still relatively little research studying the potential social impacts of new role activities.

For other interest groups, innovative activities in resource management roles may be effective when they create jobs, increase economic value, or increase the share of, e.g., the bio-based economy. For example, the values held by municipalities often center on social welfare (education, jobs, health, culture), good living environments, and strong industrial competitiveness (Botkyrka Kommun 2016; Kiruna Kommun 2016). For these organizations, the effectiveness of an approach to resource management would be gauged

³⁷ Via e.g. the substitution of new (virgin) resource requirements with existing (waste) resources

according to these values. For a private WM company, care for the environment may be at the top of their corporate values, and as such they may direct strategy, resources, and development toward services and offerings that are preferable in regards to that value. However, a private WM company will need to stay profitable to sustain the organization. Therefore, new approaches to inter-organizational resource management for private WM may be judged as effective when they create new economic value while contributing to environmental value.

Broadening from personal values and the particular values of organizations, perhaps the most encompassing standards for measuring effectivity of roles are the 17 Sustainable Development Goals of the United Nations (UN 2015a). While efficient resource conservation is anticipated to assist in making progress toward these goals, attention to additional WM role activity consequences (e.g. decontamination of resource flows, and reducing the risks and burdens pushed toward future generations) will have a substantial impact when effectivity is measured in line with these concurrent values (Aid et al. 2016).

From such macro perspectives on sustainability, many scientists see the necessity for continued work with resource efficiency, but also underscore the need for a diversity of other approaches to resource use such as questioning our institutional reliance on growth economies, concepts of product design, and attitudes toward consumption (Weizsäcker et al. 1998; Ehrenfeld 2000; Jackson 2009).

5.4 REVISITING THE RESEARCH APPROACH

During my PhD studies, I have been working (in a half time capacity) as a market analyst, R&D engineer, and strategy coordinator at the European WM organization Ragn-Sells. As put forth in Chapter 3, the studies in this thesis were guided by a normative foundation and pragmatic approach. In this section, a critical eye is lent to the normative and pragmatic approaches in general, alongside a reflection on how my work in a WM organization served as input into the direction of my studies.

The Normative Foundation of the Work

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 ethical and subjectivity issues 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 (Reason & Bradbury 2007; Bell & Morse 2008). I have endeavored to employ these methods to reasonable extents throughout this research via explicitly stating the focus on reducing the negative effects of resource management (Introduction) and by actively engaging other stakeholders in the formulation and enactment of the studies.

The Pragmatic Approach to the Research Questions

The thesis work took a pragmatic approach in working toward these normative objectives. While the application of a pragmatic approach is seen to have many advantages (Greene et al. 1989), there are also many challenging questions to answer in regards to the approach (Fien 2002) such as: “How do we judge the appropriateness of particular data collecting and analysis techniques?” and “Are there ways of peer reviewing our research questions?”.

For the methods and analyses utilized in this thesis, the act of judging the appropriateness is part of a plan-do-study-reflect cycle. Conscious efforts were made during the method selection, implementation, and result analysis phases to seek the input and reflection of those other than myself and my co-authors (such as workshop participants, supervisors, peer-reviewers, colleagues, etc.). Indeed, at times the approaches were questioned, and resulting methods or research questions were adjusted or complimented in further studies.

The results from studies early on, as well as experience from my work in the branch, were used to sharpen and focus succeeding research. For example, the study described in Article V is the first study to be performed in the PhD work. During and after the activities in Article V, it was clear that some stakeholders were having more difficulty (especially the WM organizations) in operationalizing new business roles than others. After some time of stagnation in pushing for more innovative offerings for C&D waste, a few colleagues pointed out that it can be very difficult to gain the organizational momentum required to realize new roles and activities without strategic and high-level buy in (e.g. the organizational board, owners, leading managers) for prospective roles or activities. Such insight lead to the studies in Papers I and II with sharper research focuses on roles and capacities as well as the ‘strategy to tactics’ approach taken in the thesis.

Another sharpening of the studies was achieved after the results of a regional symbiosis facilitation initiative in the Stockholm area (Hemmer 2011; Smedberg 2012) revealed a need for support methods to better support pre-engagement facilitative activities (e.g. regional

targeting and the pre-identification of potentials). These findings lead to the specific research questions for Paper III.

As can be seen in Papers I, III and IV, the selection of approaches to the research questions were often directed toward more hands-on activities, organizing engagement processes, building new tools, and combining methods in new manners. These studies and their research questions could have been approached in other ways which would have led to insight on other issues. For example, in approaching collaboration tactics, after initial reviews were made to situate myself in the scientific research around collaboration, different paths could have been chosen. Deeper reviews of inter-firm organizational theory or broader interviews of organizations involved in a diversity of such activities could have been viable next-step approaches (and indeed were integrated at later points in the work). However, my penchant for learning-by-doing³⁸, admittedly added some subjective bias to my selection of next-step approaches (action research engagement, and tool building). On the other hand, parallel with my decision to do an industrial PhD, I believe these decisions to more actively place my research in the ‘doing and creating’ modality produced new insight that may not have been easily elicited via other approaches.

Regarding the validity of the research questions themselves, unfortunately there is currently no formalized system for ‘peer reviewing’ the questions outside e.g. consultation with university and industrial supervisors and colleagues. There are undoubtedly core assumptions built into the framing of the research questions themselves, such as: WM companies can be effective actors in resource management activities, collaboration with external organizations is key, and new ways of applying external information can assist WM organizations in approaching new resource management roles. However, these assumptions are based on previous studies and findings (Peck 2003; van Berkel 2010; Grant et al. 2010). Additionally, a heavily bottom-up focus was taken in the question formulation, as they look to instigate action from the WM sector. Alternative focuses such as analyzing the broader regimes and context impacting waste management and waste policy such as performed by Lazarevic (2012), are also valuable approaches to exploring transitions to more effective waste and resource management. Overall, I believe the choice of questions driving this thesis, while not the only approach to the problems being addressed, were suitably embedded in previous findings in the field and resulted in adding their own novel insight to the collective work toward more effective resource management.

³⁸ Perhaps this is a result of my roots in the “Show-me State”, of Missouri.

5.5 FUTURE RESEARCH

There are many areas that could build upon or compliment the work presented in this thesis. A few of the promising areas that could be further researched to support novel roles for WM are listed below.

Innovative partnerships between WM organizations and external organizations: structure and strategy

Several interviewees in Paper I noted the importance of strategic partnerships in enabling the development and introduction of value added products and services. Some of their reasoning was grounded in the fact that secondary materials hold additional supply risk (often a result of short term procurement cycles), that new products and services required specialty knowledge from two or more organizations, and that new offerings can be too expensive for a single organization. Further research in this area could address issues such as: how long term partnerships influence the ability for WM companies to play a role in inter-organizational resource management, if/what are the inherent differences in how WM organizations organize and govern long term partnerships, and what are critical success factors for strategic partnerships between WM organizations and external parties?

Full business model exploration for new WM roles

This research uncovered and studied potential novel roles (collection of activities toward a certain customer as an incorporated provision) for WM organizations. Certain aspects such as perceived capacities for various activities and support processes were addressed, however many features of full business models were left outside the focus of the studies. Further investigating existing or potential business models for WM could study in more detail income structure, key customers, distribution channels, marketing and communication, etc.

Intra-organizational change in WM

As pointed out by Sniukas (2012), many managers and employees of companies see business as usual as “*the dominant logic of ‘how things are done around here’, how value is traditionally being created and captured is hard to break.*” Studying the key factors (e.g. barriers and lubricants) for *intra-organizational* change in a WM company would give useful insight to WM organizations looking to make the transition in some degree from business-as-usual toward more comprehensive process industries / service suppliers promoting more efficient systems.

The commodification of wastes

Various secondary materials (such as metals and paper) are traded more easily regionally and internationally thanks to detailed material classification standards, e.g. ISRI (2016). For companies looking to market secondary materials, such as regional IS facilitators and secondary resource extractors, a lot could be learned from studies into how such national and international standards were established.

Environmental, social, and economic impacts of new roles and business models

Instituting IS and circulating materials has been shown to provide a range of environmental, economic, and social benefits (Chertow & Lombardi 2005; Laybourn & Lombardi 2007; Martin 2013; Wijkman & Skånberg 2015). However, the true effectiveness of instituting new inter-organizational resource management and secondary resource extraction roles will depend on factors such as geographic region, material and energy efficiency gains, current and background systems, etc. Studies quantifying the existing or potential benefits of new services should help ambitious WM organizations communicate how their ongoing/potential novel activities align with broader goals in their working regions.

The application of computer assisted tools in broad development frameworks for WM

The tactical tools designed and proofed in this study have yet to be tested in broader innovation frameworks (from identification to commercialization). Studies together with WM organizations or regional authorities on the effect of these tactical tools, their perceived benefits and drawbacks, and improvement potentials would help in verifying and further developing supporting tactics for roles such as regional IS facilitator and eco-industrial park manager.

CHAPTER SIX

6 CONCLUSIONS

Grounded in the theory, systematic approach, and key tenets of Industrial Ecology, this thesis looked to develop knowledge for assisting the waste management sector in identifying, developing and implementing resource management services which can contribute toward more effective and efficient resource management. Toward this aim, a range of analytical and applied activities were conducted to address two specific research questions focused on 1) the potential roles available for WM firms, and 2) tactics to support new and existing roles.

In exploring the potential roles for WM firms, two studies were conducted. The results of these studies underscored the fact that the Swedish WM sector already holds key capacities to ease and in some instances overcome many barriers to inter-organizational resource efficiency. However, some capacities will need to be strengthened or established. Specific roles identified were: regional IS facilitator, eco-industrial park manager, holistic facility management provider, and high value resource extraction performer. Risks identified related to the further development of such novel roles centered on supply instability and capital investment risk. Opportunities identified included those of expanding customer base, staying ahead of evolving markets, and the ability to work toward multiple organizational values (such as environmental and economic values) in concert.

Key issues which emerged regarding the further development of novel roles, centered on market factors, long term partnerships, utilizing expansive information resources, and the development of new business models. It is suggested that WM organizations actively communicate to regional and national authorities the importance of critically assessing market mechanisms and resulting steering implications from broader systemic perspectives when looking to be more effective in achieving sustainability goals. Toward enabling new management roles, the tactic of long term partnerships was highlighted, especially in situations where the market risks are high and new critical competencies are required. In looking toward new offerings, alternative approaches to providing customer value need to be developed and reviewed. Developing new business relations and reassessing business model formation (e.g. income structure) are suggested to assist in such activities. Looking toward the establishment of stronger knowledge bases, WM organizations could, e.g. recruit or develop new internal capacities, establish partnerships for filling knowledge gaps, or find

new methods for effectively utilizing various knowledge resources developed both externally and internally.

To study tactical approaches for inter-firm collaboration, a hands-on action research procedure was applied toward the management of construction and demolition waste. The procedure employed systems analysis tools for the measurement of key indicators, collectively formulated by a range of stakeholders. Collaboration methods, such as workshops, focus groups, and collaborative system mapping were utilized to gain better understanding of the resource flows, the systems' relations, and potential improvement activities. Through the various action phases of the case, new insights to bottlenecks and opportunities arose. In the short term, new opportunities were demonstrated and commercialized – such as the introduction of CE certified 100% recycled aggregates on the market. Issues regarding bottlenecks were carried forward in continued collaboration and development constellations on the regional, national, and EU levels.

While this approach to inter-firm collaboration was effective in engaging a range of stakeholders in a resource system and creating a degree of change and new resource value, it is uncertain if the role of central facilitator should be taken on by organizations in WM branch as they stand now. New capacities for coordination, information collection and dissemination, and knowledge distribution will need to be enlisted externally or developed internally. Alternatively, such activities could be undertaken by specialized branch organizations.

Two tactical procedures for data analysis were developed and tested in exploring the potential for using external and internal information to support inter-organizational resource management roles. Both approaches aimed to improve the user's ability to identify novel opportunities. The Looplocal tool focused on the identification of new material symbiosis potentials while the text analysis study focused on identifying new value pathways for waste material in the Bio Based Economy. These approaches identified diverse valuation opportunities, but their effectiveness cannot be completely determined until more extensive tests are performed within the complete framework of product and service development (identification, evaluation, development, and commercialization). Improved best practice databases, better waste taxonomies, weighting techniques for results, and improved interactive visualizations were identified as some of the future research and work needs.

Overall, organizations in the Swedish WM sector are massively redirecting their business visions. Supporting this shift can translate into new approaches and value creation roles –

from a heavy focus on sanitation and removal of waste toward a broader focus on critical resource production and inter-organizational resource management. The work found that organizations in the WM sector held the potential to be very effective in creating novel resource management value moving forward. However, to perform these new roles, specific capacities in regards to identifying and developing new products, approaching inter-firm initiatives, and enlisting knowledge capital will need to be further researched and strategically developed.

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Appended Papers

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