CHALMERS
UNIVERSITY OF TECHNOLOGY

The influence of organisational practices on environmental performance

A screening of the organising of nodes in product life cycles in six test cases

MATHIAS LINDKVIST
HENRIKKE BAUMANN

Department of Energy and Environment
Division of Environmental Systems Analysis
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden, 2015
Report no. 2015:14

REPORT NO. 2015:14

The influence of organisational practices on environmental performance

A screening of the organising of nodes in product life cycles in six test cases

MATHIAS LINDKVIST & HENRIKKE BAUMANN

Department of Energy and Environment
Division of Environmental Systems Analysis
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden, 2015

The influence of organisational practices on environmental performance
A screening of the organising of nodes in product life cycles in six test cases

MATHIAS LINDKVIST & HENRIKKE BAUMANN

Report no. 2015:14
Department of Energy and Environment
Division of Environmental Systems Analysis
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31 772 1000

Chalmers reproservice
Gothenburg, Sweden, 2015

The influence of organisational practices on environmental performance

A screening of the organising of nodes in product life cycles in six test cases

MATHIAS LINDKVIST & HENRIKKE BAUMANN

Department of Energy and Environment

Division of Environmental Systems Analysis

Chalmers University of Technology

SUMMARY

In the here reported on project, we have screened relations between product life cycle environmental performance and organising traced from technical processes that are *nodes* by having central roles in these cycles. Thereby, we have aimed both to further an already introduced method for this type of study by introducing an approach that is quicker to use than the thorough design previously deployed and to test it on a broader range of empirical domains.

The method used combines life cycle assessment (LCA) and organisational studies, which are coherently integrated with each other using particularly the *socio-material* approaches *actor-network theory* (ANT) and *action nets*. The screening approach was applied to six test cases that covered six different types of services and physical commodities, and for each of these six comparisons have been performed between the organising traced empirically from at least three different nodes and their product life cycles environmental performance. The cases have covered the products and nodes listed in table S.1, further on in this summary.

Table S.1: Test cases covered in this project. Products and nodes in the cases.

Product	Nodes
Bowling	Bowling halls in Gothenburg, Sweden
Bread	Bakeries in Gothenburg and Malmö, Sweden
Bus travel on intercity routes	Bus travel routes between Gothenburg, Sweden and Oslo
Cement	Cement plants in Sweden
Properties management	Properties in Gothenburg, Sweden
Road management (operation and routine maintenance of roads)	Road administration areas used in the larger Gothenburg area, Sweden

The test case on properties management was based on existing publications on a thorough study using the combination of LCA and organisational studies, while the other five test cases were performed as screenings applying this combination approach for the first time.

A large number of practices of this organising have been indicated potentially to considerably influence product life cycle environmental performance. These organisational practices have been indicated to vary considerably between different activities both regarding the practices themselves and regarding the discernibility of their relations to each other and of their influence on environmental performance. The approach used in the project necessarily has limitations due to its screening characteristic, but these can be seen as prerequisites both for identifying the large number of organisational practices with indicated large influence on environmental performance and for reaching the overarching indications made through the project.

However, even if no direct quantitative environmental differences were possible and feasible to present, the screening has at least shown that the environmental performances of the studied product life cycles seemed considerably to depend on organisational practices through not straightforward interplays between organising, technology and materials and energy processes. These organisational practices include the examples presented in Table S.2, further on in this summary.

Table S.2: Examples of organisational practices that were identified to influence environmental performance

Test case product	Examples of organisational practices that were identified to influence environmental performance
Bowling	Ceasing of business or not
	Lunch provision or not
	Additional games and similar activities degrees
Bread	Supply transport distance
	Bread thickness and baking
	Overproduction
Bus travel on intercity routes	Eco-driving training and discussions degrees
	Number of routes served by the ticket offices
	Seats organisation differences on the buses
Cement	Production permits renewal procedure differences
	Production permit expiration criteria differences
	Organisational practices for handling technical problems at and operation of the plant differences
Properties management	Types of windows related to the handling of cultural heritage requirements
	Water taps replacement related to renovation and emergencies, system knowledge and operation and maintenance differences
	Insulation differences due to fire protection differences
Road management (operation and routine maintenance of roads)	Renewal or not of procurement contracts
	Centralisation of contractors activities
	Fragmentation of procurement governance

Regarding overall usefulness of screening and thorough nodal LCA organisation studies, respectively, generally the screenings were found to be considerably useful but instead performing thorough studies was indicated to provide considerable additional usefulness although the level and type of this addition were generally found to be difficult to predict. In relation to this, the results have also been discussed regarding whether and if so how they may point towards more overarching ideas on considerable reductions of society's environmental impacts. This has covered internally driven environmental work within the organising connected to and along

product life cycles, substantial amounts of assistance in such work from external experts, and an approach to focus of with a global coverage letting the local activities where the environmentally impacting resource use and emissions occur be monetary targeted. The actual feasibility of each of these approaches, however, have been found to be more or less limited and a uniting requirement seem to be a considerable pressure from the public. Finally, even if such considerable undertakings are made the project here reported on suggests that the environmental effects of a considerable share of actions still may not be possible or feasible to foresee.

Keywords: organisational practices, life cycle assessment (LCA), empirical cases, socio-material, screening, management, organising, environment.

CONTENTS

1. Introduction 1

1.1. Aim and research questions 2
1.2. Outline 3

2. Literature background and core method approaches 5

2.1. Previous research 5
2.2. Life cycle assessment (LCA) 5
2.3. Combining LCA and organisational studies 6
2.4. Interaction concepts for combined studies of LCA and organisational aspects 7

3. Methods in practice 9

3.1. Empirically based study 9
3.2. Research techniques and procedures as applied in practice 9

4. Bowling (based on test case 1) 17

4.1. Study objects 17
4.2. Life cycle assessment screening 19
4.3. Socio-material points of interaction at the product life cycles 25
4.4. Overall planning (A) 26
4.5. Types of services provided (B) 28
4.6. Premises maintenance and planning (C) 31
4.7. Analysis and summary of the test case 34

5. Bread produced in bakeries (based on test case 2) 40

5.1. Study objects 40
5.2. Life cycle assessments review 42
5.3. Socio-material points of interaction at the product life cycles 46
5.4. Purchasing of supplies (A) 46
5.5. Production automation and product focus (B) 50
5.6. Production intervention approaches (C) 56
5.7. Retailer aspects (D) 59
5.8. Analysis and summary of the test case 62

6. Bus travel on intercity routes (based on test case 3) 69

6.1. Study objects 69

6.2. Life cycle assessment screening 71
6.3. Socio-material points of interaction at the product life cycles 72
6.4. Driving style (A) 73
6.5. Ticket sales (B) 74
6.6. Garage practices (C) 76
6.7. Fleet management (D) 78
6.8. Analysis and summary of the test case 80

7. Cement (based on test case 4) 85

7.1. Study objects 85
7.2. Life cycle assessments review 86
7.3. Socio-material points of interaction at the product life cycles 88
7.4. Negotiations between cement producers and environmental authorities (A) 88
7.5. Maintenance and operation of cement plants (B) 91
7.6. Analysis and summary of the test case 93

8. Properties management (based on test case 5) 98

8.1. Study objects 98
8.2. Aspects connected to life cycle assessment considerations 102
8.3. Socio-material points of interaction at the product life cycles 103
8.4. Energy-based services and their management, according to account I on HSB and Fambo (A) 104
8.5. Energy-based services and their management, according to account II on Dalavik and Wallenstam (B) 107
8.6. Water-based services and their management, according to account I on HSB and Fambo (C) 110
8.7. Water-based services and their management, according to account II on Dalavik and Wallenstam (D) 114
8.8. Analysis and summary of the test case 117

9. Road management (based on test case 6) 125

9.1. Study objects 125
9.2. Life cycle assessments review 127
9.3. Socio-material points of interaction at the product life cycles 128
9.4. Procurement related management by the procurement contract holders (A) 128
9.5. Management by procuring organisations (B) 130
9.6. Analysis and summary of the test case 133

10. Overall analysis 139

11. Discussion 155

12. Conclusion 158

ACRONYMS

ANT = actor-network theory (concept)

AP = acidification potential (concept)

CO_2 = carbon dioxide (compound)

EAO = environmental assessment of organising (research framework)

EP = eutrophication potential (concept)

GWP = global warming potential (concept)

Hg = mercury (compound)

IE = industrial ecology (research field)

LCA = life cycle assessment (method)

OrM = organising for the environment (research programme)

SO_2 sulphur dioxide (compound)

NO_X nitrogen oxides (compound)

1. INTRODUCTION

This report aims to expand the knowledge on how *environmental impacts* are related to *human use of materials and energy that generate environmental impacts* and to *how these activities are related to other human activities*. We report on a broad and exploratory project that is based on the environmental performance perspective in life cycle assessments (LCAs), which follows *product life cycles* (cf., e.g., Baumann and Tillman, 2004), and that has focused on the *organisational practices* (cf., e.g., Czarniawska, 2005) that can be traced from *material and energy hubs* of these life cycles (cf. Baumann, 2012). At the overarching level, this report thereby intends to contribute to facilitating the highly requested transformation to a significantly less environmentally impacting society (e.g., IPCC, 2007, 2014; WRI, 2005).

Through studies in or closely related to the research field industrial ecology (IE), it has been shown that it is relevant to base measures for reducing anthropogenic environmental impacts on an understanding of how these are generated via often large and non-linearly intra-connected systems of material and energy connections. The focus of this research lies on the *technical aspects* of these *material and energy systems* and on these systems' environmental performances. (cf. Ayres and Ayres, 2002; Journal of Industrial Ecology, 2014.)

However, human actions are required for and largely affect the generation of all anthropogenic environmental impacts. These actions are for example the operating of machines at manufacturing plants and consumers' use of products. Further, such actions are the outcome of and are shaped by other activities, such as the practices of other employees at the manufacturing plants and these practices' coordination with or non-coordination with the behaviour of consumers.

The importance of considering such *organisational aspects* and not least *management*, has been pointed out in IE (e.g., Boons and Howard-Grenville, 2009; Journal of Cleaner Production, 2015; Journal of Industrial Ecology, 2014; Korhonen and Strachan, 2004; Piasecki, 1992). However, only little progress has been seen in IE research on organisational aspects from the take-off of the IE field in the early 1990's until now (2015) (Baumann, 2008, 2012; Lindkvist and Baumann, 2014; cf. Boons and Howard-Grenville, 2009; Korhonen and Strachan, 2004; Piasecki, 1992).

A similar untapped potential for integrating research on organisational aspects, and technical and environmental aspects of material and energy systems seems to be present in environmentally oriented research in management science and organisation studies (Baumann, 2008, 2012; Kallio and Nordberg, 2006; cf. Molina-Azorín and López-Gamero, 2014; Tung et al., 2014; Vazquez and Liston-Heyes, 2008).

In order to address this issue, research on several *populated LCA* approaches has been performed. This includes the mentioned approach followed in the project here reported. In the approach, which is denoted *nodal LCA organisation studies*, LCAs are combined with studies of the organisational aspects that can be traced from and are particularly considered in detail at *nodal technical processes* of the product life cycles. These processes are *nodes* (in the sense of being hubs) by handling multiple environmentally important inputs as well as outputs of materials and energy. (Baumann, 2012.)

The approach has previously been tested in and developed through studies on residential properties management (Brunklaus, 2008, 2009a) and in a pre-study on facilities management for supermarkets (Lundberg, 2008), and findings from the project here reported on has previously been partly presented by Lindkvist and Baumann (2010). The publications on these studies have shown that how organisational practices identified via a nodal technical process in a product life cycle are performed considerably influences the life cycle's environmental impacts, and that it is feasible to study how this occurs. (Baumann, 2004, 2008, 2012.) However, these pilot studies on properties management was based on a thorough and resource intensive approach and both the pilots and the pre-study only empirically covered two specific domains.

1.1. Aim and research questions

The project presented in this report has aimed to further the combining of LCA and studies of organisational aspects traced from nodal technical processes of product life cycles. This has covered both the exploration of a quicker approach to such nodal LCA organisation studies than the one used in previous pilot studies, and the testing of the nodal LCA organisation studies on a broadened range of empirical domains. In the project, the overarching approach was an exploratory screening that at the same time was moderately detailed and this led to the inclusion of six test cases. These cases empirically covered six different products and their product life cycles and organising.

The aim of the here reported on project has been operationalised by searching for answers to five interrelated research questions. They were designed to lead to an open-minded consideration of and mapping of the targeted environmental impacts, product life cycles, and organisational aspects. Further, these questions were designed to relate this consideration and mapping to currently established research methods. The questions are:

- **Which practices?** For which organisational practices that are identified via nodal technical processes of the product life cycles covered in the cases, could it be indicated that the environmental impacts of these life cycles differ between different through empirical material identified actual ways of performing these practices?

- **How are practices and impacts related?** How are these practices indicated to affect and to be affected by these life cycles and their environmental impacts?

- **Which method?** How can the relations between these practices and the taken together environmental impacts from these life cycles be visualised and described in ways that align as much as feasible with established research methods, and in particular with LCA?

- **Which type of study seem to be required?** Is a simplified LCA enough for providing a useful understanding? If not, what is required and what can the approach provide: a full standard LCA, a screening nodal LCA organisational study using a simplified or full LCA, or a full nodal organisation LCA study using a simplified or full LCA?

- **Potential implications for considerably reducing environmental impacts in society?** Whether and if so which suggestions for considerably reducing environmental impacts in society are pointed towards by the project?

1.2. Outline

In the subsequent chapter, a more thorough outline of the background literature and the core method approaches used in the project here reported on is given. In chapter 3, we describe the method procedure and the specific methods components used when the project was performed in practice and how these relate to this report's design. The chapter includes presentations of the criteria for the selection of, general coverage of, and delimitations of the test cases.

The six test cases are then reported on. The design of and results from these cases are presented in chapters 4–9, were each chapter covers one of them. In each of these chapters, initially a general introduction is given of the respective product that the case has covered, the *nodal sites* at the nodal technical processes focussed on, and the product's environmental performance from an LCA perspective. This is followed by a description of how that particular case was performed (first sub-chapter). Subsequently, a more detailed presentation is given of the environmental characteristics of the product's life cycle and when relevant with a focus on the considered nodal technical process (second sub-chapter). Thereafter, the identified indicated environmentally significant organisational practices are introduced through case specific groups of practices (third sub-chapter). These groups are used to create an overview of the practices. Each of the subsequent sub-chapters (starting in the fourth sub-chapter) describes findings related to one of these groups. Finally, a combined presentation is made of an analysis of and a summary of the case in the chapter (last sub-chapter).

Subsequently, in chapter 10, a synthesis of the here reported on project is presented. In chapter 11, it is discussed regarding how useful its design was for pursuing its aim and regarding potential

implications for considerably reducing environmental impacts in society. The conclusions from combining chapters 10 and 11 are presented in chapter 12.

2. LITERATURE BACKGROUND AND CORE METHOD APPROACHES

In this chapter, the general research approach used in the project here reported on is described. Both the literature background and the selection and development of the core method approaches that the project is based on are outlined. First, the two related interdisciplinary research approaches that the project is a continuation of are described (2.1). Then, the LCA method, which was used as one of the bases in the project, is described further than this far in this report (2.2). Thereafter, the approach used to combine this LCA basis with organisational studies is outlined (2.3). Finally, three previously not specified aspects on interactions that are part of organisational practices and that were found to be particularly useful in the project, are presented (2.4).

2.1. Previous research

The project here reported on is a continuation of research based on an approach denoted *environmental assessment of organising* (EAO), and of the research programme *Organising for the Environment* (OrM). EAO targets how management practices and other organisational practices influence environmental performances of material and energy systems. The EAO research has earlier resulted in three already in this report mentioned nodal LCA organisation studies – two comprehensive pilot studies and one pre-study. (Baumann, 2004; Brunklaus, 2005, 2008, 2009a; Lundberg, 2008.) The two pilot studies have together been used as the basis in one of the six test cases in the project here reported on.

OrM addresses the, compared to EAO, broader issue of relations between management and organisation, and the natural environment (Baumann, 2008). The OrM research includes two, to EAO additional, studies: one on the management of water resources (Adolfsson, 2005, 2007) and one on how environmental issues are shaped in a company (Rex, 2007).

2.2. Life cycle assessment (LCA)

The well-established LCA method is in the project here reported on used as a basis. LCA provides a framework for studies focussing on the environmental consequences of the often large and non-linearly intra-connected systems of technical processes transforming, transporting, and storing materials and energy along the life cycles necessary to provide products. It aims to account for as many as feasible of the non-negligible contributions to known environmental impacts caused by these processes.

The product life cycle considered in an LCA generally stretches from raw material extraction, via intermediary products production, final production and use to end-of-life processes including

waste management, and covers transports along the life cycle. Therefore, the systems covered often crosses both geographical and organisational borders. In addition, it can be noted that this view of the life cycle of a product is based on the prominent physical connections. Thus, it is not based on for example the product life cycle typically starting with the innovation of a product and via the setting up of its production, in-place production and sale of it, and product development stretches to the seizing of producing it. (Klöpffer, 2014.) Finally, the *products* considered in LCAs can be either *physical commodities* or *services*.

For further descriptions of LCA, see, for example, Baumann and Tillman (2004) and ISO (2006a, b).

2.3. Combining LCA and organisational studies

The project here reported has combined the LCA basis with studies of management and other organisational aspects through a *socio-material* approach. *Socio-materiality* is a perspective that takes both humans and nonhumans – such as machines, buildings, other materials, energy, and other living organisms – into account and treat all of them as potentially actively shaping activities and affecting each other (e.g., Åsberg et al., 2012). A main reason for using this specific and integrated approach is the design of and findings from earlier EAO and OrM studies that were informed by a few specific socio-material approaches. These studies resulted in findings where it was shown that the environmental performances of material and energy systems were largely influenced by how organisational practices were performed, and that these practices included for the environmental performances critical interactions where humans and nonhuman entities at the technical processes in these systems affected each other. (cf., e.g., Baumann, 2008.) Four specific socio-material approaches were used in these earlier EAO and OrM studies. These approaches are the 'hybrid' method approach *actor-network theory* (ANT) (e.g., Callon, 2001), the ANT 'cousin' *action nets* (e.g., Czarniawska, 2004), and environmentally oriented anthropology and sociology (e.g., Guy and Shove, 2000, cited in Baumann, 2008), and these have in the project here reported on been used as a starting point. The first two of them are related to in the following and the latter ones are related to in the subsequent sub-chapter.

The general relevance of combining studies based on LCAs with the study of practises that consider both humans and nonhumans via ANT is multi-fold. One reason is that ANT has been described as the only socio-material approach that contains actual conceptualisations of the socio-material relations. It also seems feasible for studies of the technical components often largely present in contemporary material and energy systems since ANT was initially developed through studies of how scientific claims are created and used and technology is produced and used. (Callon, 2001.) *Actant, translation*, and *network* are three of the most prominent conceptualisations from ANT studies that have been found to be of relevance for the project here reported on. They are in ANT studies of science and technology used together for describing that the identified activities

have been found to consist of or depend on processes that regarding themselves and their inter-relations are not necessarily discernible and that involve human and nonhuman entities that constantly change through interactions with each other. The human actions are in ANT presented as being dependent on actants, which are nonhumans that act and thereby have impacts on humans or on other nonhumans. In order to understand how meaning and useful artefacts are created and used, ANT thus argues that humans as well as nonhumans need to be considered as potentially active. Translations refer to processes of aligning to each other that different entities have been found to perform, and which have been deemed necessary for the production of this meaning and these artefacts and for circulating them in networks where their uses and contents may be renegotiated and changed through further translations. (cf., e.g., Callon, 2001.) In an LCA context, these concepts point out, among other, that different persons and nonhuman entities in management and other organisational practices related to the environmental impacts generating processes of product life cycles may change each other via interactions. Further, due to the often large and not necessarily discernible networks connecting for example top management and the blue collars that handle the material and energy system, these entities may be interrelated through such networks of interactions.

The action nets approach is similar to ANT by aiming to capture how human and nonhuman entities and actions are affecting each other through networks or nets that may be large and not necessarily discernible. However, the basis of the ANT approach is studies of laboratories, and the action nets approach points out that relations found there in many senses are organised clearly hierarchically. Closely related to this, it highlights that those entities have already become, to a high degree, established by being institutionalised. (Czarniawska, 2004; cf. Latour, 1987.) In order to complement this approach, action nets provide a more constructivist perspective where processes rather than entities are focussed upon. Particularly, the approach includes actions that do not lead to the formal establishing of entities, but lead to the formation of entities that are less rigid or present for a shorter time-period only. (Czarniawska, 2004, 2005.) In an LCA context, this puts emphasis on considering processes of organising and not only or mainly the involved entities such as different employees and artefacts, as potentially central for understanding well how organisational aspects are connected to the environmental performances of product life cycles.

2.4. Interaction concepts for combined studies of LCA and organisational aspects

In order to provide a sufficiently clear picture of the main approach in and the results from the project here reported on, three concepts on interactions are here presented. First, the concept *socio-material interaction point at the product life cycle* is used to highlight aspects of the

interfaces between humans and product life cycles and their environmental performance. It is based on the earlier derived concepts socio-material interaction and interaction point, which were inspired by environmentally oriented anthropology and sociology (cf., Baumann, 2008). The socio-material interaction point at the product life cycle concept puts focus on that the connections between organisational practices and the environmentally impacting processes of product life cycles occur via interactions between humans and the nonhumans of the technical processes of these life cycles. These interactions denote the closest that humans come to the actions that ultimately determine the environmental performances of these life cycles. In addition, it is traditionally the dividing line between LCA and organisational studies and has therefore only been little explored (cf., Baumann, 2012). As a further consequence, it risks being overlooked if not explicitly pointed out. These interactions can for example be the programming of a monitoring system at an industrial plant, the blue collars that construct the equipment that interacts with the material and energy system of a product studied, or the manual moving of materials that are part of a product life cycle.

Second, and related to this concept, the concept *socio-material interaction point within organisational activities* is used to denote that for this type of study relevant interactions between humans and nonhumans in addition can occur within organisational activities that are not located directly at a product life cycle. Examples of socio-material interaction points within organisational activities are human interactions with building interiors and communication systems.

Third, and finally, *furthest traced interaction* is introduced in this report as a concept. It points out the interactions that are the furthest to which the 'origin' of the organisational practices, with an indicated influence on environmental performance, are traced in the project here reported on. It has been considered to be of relevance to trace these as far as feasible. Thereby an understanding is particularly sought of not only socio-material interaction points at the product life cycle, but also of other involved activities. These could be practices located at other companies along the product life cycle, at authorities, or at sector organisations. At the same time, the concept highlights that it has only been relevant or possible to trace them to a certain extent.

3. METHOD IN PRACTICE

In this chapter, the method used in practice in the project here reported on and its relation to this report's design are presented. The coverage of the method used in the project includes both research techniques and procedures used for applying these. First, the approach to selecting these techniques and the overarching way of applying them is presented (3.1). Second, the techniques and procedure used in practice are presented, and when applicable they are compared to the design of this report (3.2). This is performed for the following topics: the use of a screening of test cases (3.2.1), focuses derived from experience from previous similar studies (3.2.2), overview of test cases (3.2.3), LCA based study in practice (3.2.4), organisational study in practice (3.2.5), combined study in practice (3.2.6), and results organisation used in the project (3.2.7).

3.1. Empirically based study

The method approach used in the project here reported on is *empirically based*. This lies much in line with *grounded theory*. Grounded theory is a strategy for effectively formulating theoretical explanations from empirical material. The approach to perform this is that previously collected field data, in the current project and from previous studies, is repeatedly re-analysed as new data is collected. Thereby as relevant as possible explanations are sought, and the aim is to maximise the progress in theoretical conceptualisation in relation to effort spent on retrieving and analysing data. Further, in order to make this data collection even more effective, the grounded theory approach suggests the use of the most suitable data collection technique for each situation whether it is for example observations, interviews, measurements, document studies or literature reviews. (Glaser and Strauss, 2006.) In carrying out the project here reported on, all of the above mentioned collection techniques except measurements have been used. Further, the use of collection techniques have when necessary differed between the six test cases and within these.

3.2. Research techniques and procedures as applied in practice

3.2.1. Screening of a moderate number of test cases

For several reasons, a general frame for the project here reported on has been a screening of a moderate number of test cases. Thereby, the project both covered several different empirical domains and still reached a moderately detailed level for each of these domains.

In the project here reported on, the number of test cases screened was not determined initially. On the other hand, it was based on the need for reaching sufficient findings for the aim of the project, in accordance with the empirically based approach.

Within each test case, product life cycle environmental performance and organising related to a technical node were compared between at least three different *sub-cases* in order to gain the benefit of opening up new perspectives that comparative studies have been considered to facilitate, and which as well lies in line with the empirically based approach.

3.2.2. Project focus based on previous findings

A few findings from previous studies using the EAO approach were found to be useful for focusing the project here reported on. First, in this relatively early phase of nodal LCA organisation studies, it has been found suitable to "[keep] the technology (relatively) similar in [the] comparisons" (Baumann, 2004, pp. 298–299) of product life cycles and their organisational and environmental aspects. This means that within each test case in the project here reported on, the sub-cases were chosen to be similar in important aspects. These include in the project here reported on for example cement production with a focus on nodal sites that were the then three active cement plants in Sweden, and bowling services with nodal sites that were bowling halls open to the public and located in the central parts of Gothenburg, Sweden. Thereby, the aim was to minimise the risk of confusing differences in practices with variations in for example production technology, climate conditions, and types of customers. Following this reasoning further, the study objects within each test case have been chosen to be geographically closely located. However, based on the mentioned often many components in product life cycles and on the intertwined understanding of human and nonhuman entities and actions that particularly ANT suggests, such a minimising of variation in certain parameters have in the project here reported on been seen as likely only being partly achievable. Further, and as well supported by applying an ANT perspective, if some parameters are chosen to be too similar this might result in less possibility to discover variations in the parameters that are of primary interest.

Second, in order to be able to study organisational practices in detail and thereby get a thorough understanding of them, one suggestion has been to focus on a few parts of a site or a formal organisation. This was one conclusion from the EAO pre-study mentioned previously in this report. From its study of facilities management, it was concluded that it would be advantageous to "focus on the management of one or two appliances in a building rather than attempting to study the management of an entire building." (Lundberg, 2008, p. 52) This approach was in a sense followed in the project here reported on, by focussing on the aspects that were most obviously potentially relevant in the limited amount of empirical material possible to locate and analyse in each of its sub-cases. In addition, some of the formal organisations studied in the project were large and the empirical material related to these and found through for example study visits and documents necessarily only covered certain aspects or parts of these organisations. However, the general approach was not to decide on a few sampled parts to study on beforehand, but to use a broad approach towards the empirical material.

Third, and finally, a finding related to the highlighting of socio-material interaction points at the product life cycle is that previous EAO and OrM studies have shown the importance of "being on site, seeing the objects, dealing with stuff 'hands on'" (Baumann, 2008, p. 21). This both has led to focussing on whether the organisational practices found through the project here reported on follow these criteria, and has inspired the project design to use on site visits when possible.

3.2.3. Overview of the selected test cases

In total, a screening was, as mentioned, made of six test cases in the project here reported on. Five of these cover services and physical commodities that considerably differ from the ones earlier covered in nodal LCA organisation studies. In addition, as mentioned previously in this report, the earlier performed pilot studies were together used as the basis of one of the six test cases, with new perspectives added to these pilot studies through the different design of the project here reported on compared to them. A coverage of both services and physical commodities in the six test cases was chosen in order to cover a wide range of activities in society.

For each of the six test cases, as mentioned, at least three product life cycles and nodal sites, respectively, have been covered. In accordance with the LCA method, the environmental impacts have been related to the same function, the functional unit, such as one kg of a product (cf. Baumann and Tillman, 2004), in each of the sub-cases within the respective test cases. The products in and foci of the test cases were selected based both on previous studies pointing out organisational practices with a potential influence on product life cycle environmental performance, and on additional properties that seemed relevant to cover in the project. The project was designed to make it feasible to study not only the organisational aspects at the nodal technical processes chosen, but also to them connected organisational aspects such as organisational practices at other technical processes of the product life cycles. Therefore, product life cycles with limited extensions geographically were selected.

In Table 3.1, further on in this sub-sub-chapter, the six test cases are listed, and information is provided about the nodal sites, about whether each case concerns mainly a service or physical commodity and about the mentioned on beforehand pointed out additionally seeming relevant to cover characteristics. Two of the cases focussed on the respective physical commodities bread produced in bakeries, and cement. Four services were included: bowling, bus travel on intercity routes, properties management (based on the previously performed pilot studies), and road management (operation and routine maintenance). A more detailed overview than in Table 3.1, and where the basic properties of the sub-cases as well are listed, is found in the Appendix, in Table A.1 and Table A.2.

Table 3.1: Overview of the screened six test cases

	Study object		Service or physical commodity	Previously studied potentially environmentally significant practices	Additional properties that made the test case relevant in combination with the other test cases
	Product	Nodal site studied			
1	Bowling	Bowling hall	Service		Substantial part of the leisure sector, which has only been little studied from an environmental perspective (cf., e.g., Algehed and Winnes, 2010; SBHF, 2012)
2	Bread produced in bakeries	Bakery	Physical commodity	Scale of business of bakeries (Andersson and Ohlsson, 1999) Incompatibility of work hours and automatic baking (Sennett, 1998, cited in Brunklaus, 2008, p. 37)	
3	Bus travel on intercity routes	Bus travel operation route	Service		Part of the transport sector, which contributes to major shares of society's environmental impacts (e.g., UNFCCC, 2005, 2014)
4	Cement	Cement mill	Physical commodity	Production pattern (von Bahr et al., 2003) Limitations in measurements (von Bahr et al., 2003)	Very large environmental impacts both by absolute numbers and in relation to its share of the economy (cf., e.g., Cementa n.d.) Already monitored to a large extent (cf., e.g., Cementa 2008b)
5	Properties management	Property	Service		
6	Road management	Procurement district for road operation and routine maintenance	Service	Procurement continuation (Faith-Ell et al., 2006)	Use of procurement (Faith-Ell et al., 2006)

3.2.4. Life cycle assessment based overview

As one out of two main pillars, each of the six test cases in the project here reported on were based on an *LCA based overview* approach. The reason for using an overview approach rather than *full LCAs* has been the twofold. Full LCAs require substantial studies that the limited amount of

resources per case and sub-case did not allow. In addition, a full LCA are usually only performed for one specific product and this would not cover the broader sector wide practices that were of interest due to the explorative approach of the project.

This overview approach was carried out through specific methods that varied between the test cases. Reviews of existing LCA reviews and existing LCAs were performed where such studies were available. For the test cases that such studies could not be located relatively easily, a combined approach was applied that combined qualitative overviews and quantitative results from LCAs on similar products.

In line with the overview approach to LCA, an *attributional* approach (cf., e.g., Finnveden et al., 2009) was used in the project here reported on. Contrary to the, so-called, consequential approach, it does not follow material and energy cause-effect relations outside of the technical processes strictly attributed to each product life cycle. The result is that, for example, the side effects in society that consequential LCA commonly estimates using price elasticity models from microeconomics are not accounted for in the project. (cf. Finnveden et al., 2009.)

Regarding the specific test cases in the here reported on project, the properties management case used the in the original publications on the pilot studies presented fully quantified conclusions on energy and water use related to the practices there studied. In the other test cases quantifications have as far as feasible been used considering the screening characteristic of the project. Therefore, the outcome regarding most organisational practices covered are qualitative descriptions that are backed up by quantitative background data from secondary sources.

LCA has been repeatedly used and refined for many physical commodities (Baumann and Tillman, 2004), but services, which represent the major part of the screening project here reported on, have been less studied using LCA. LCA is seen as a product generic approach, suitable for both physical commodities and services (ISO, 2006b, p. 2), but a review by Brunklaus (2009b) found only few service LCAs having been performed. Particularly, according to Brunklaus, the cut-off criteria that determine which activities to include and not to include in each service LCA have varied.

3.2.5. The organisational study in practice

The other main pillar of the project here reported on concerns to product life cycles connected organisational activities that include human as well as material actions and entities. Following the empirically based approach, test cases and sub-cases adapted combinations of observations, interviews, and document studies have been performed. The starting points for these studies were at the socio-material interaction points at the product life cycles that are the closest direct connections between humans and the environmentally impacting processes of product life cycles. Further connections via organisational activities including management, or the possibility to find such connections, were explored. This included, particularly, the relations that connect to socio-material interaction points at the product life cycles at, for example, the company level or site

level. In practice, however, it was regarding most of the indicated environmentally significant organisational practices covered, partly due to the screening character of the project, not possible to on site closely study human handling at the product life cycles. Thus, the approach was to look for possibilities to relate to them particularly during study visits and interviews. For similar reasons related to the limited resources due to the screening characteristic of the project, an understanding of the quantitative properties of the organisational aspects were sought for but in practice the emerging descriptions were focussed on a qualitative representation of them.

3.2.6. The combined study

The performing of the combined study of LCA and organisational aspects here reported on differs from how it is presented in this report. The studies of aspects of product life cycles, environmental impacts, and organisational practices informed each other. Therefore, they were carried out in parallel to each other and in an intertwined way, and these procedures varied between and within the test cases. This report, on the other hand, is structured in a more topical way, to facilitate among other its accessibility.

The results from each test case in the here reported on project are in this report presented through series of texts, tables and figures. The tables and figures are used for giving overviews of the reported on organisational practices and their indicated environmental significance within the groups that are used to facilitate the presentation of the findings from each case.

Figures are used for, among other, relating the findings to standard LCAs. A figure representation used for an earlier LCA study of two services – one on theatre performances and one on opera performances – reported on by Tengström and Izurieta (2010) is used as the basis for the figure design. This is relevant since four out of the six test cases were more service oriented than physical commodities oriented, but was particularly found to be useful for highlighting both similarities and differences to LCAs for the actual test cases.

As a basis in these figures, *function* is here introduced as a concept that builds on and expands the scope of an in standard LCA central unit of analysis – the technical process. A technical process can be, for example, a specific chemical transformation at a process industry or the transports between raw material extraction sites and sites for the refining of these raw materials. (cf. Baumann and Tillman, 2004.) The function concept in addition also includes other functions such as operational procedures, day-to-day practices of managers, and business strategies. Thereby, the interactions relating for example top management to environmental impacts generating materials and energy transformations that the project reported on has identified can be visualised through a held together framework that relates to standard LCA, by fully acknowledging its core strength of representing the often many components of product life cycles and only making an addition to this perspective. Due to the focus on nodal sites in the project, functions within these are in the figures used in this report to present test case result visualised with a higher resolution than activities occurring at other stages of the product life cycles.

The functions within the nodal sites are structured in similar patterns in the presentations of the results from the different test cases in order to facilitate comparisons between them, and four main groups are being used for this structure. These are: real estate and its infrastructure; other main functions, which typically are the technical processes covered in standard LCAs; directly supporting functions to the main functions; and other business functions, and the functions largely or fully relating to other actors than the actor, such as a company, that officially runs the nodal site. In order to give a further overview of the similarities and differences between standard LCAs and this approach, they are further on in this sub-sub-chapter presented in Figure 3.1a and Figure 3.1b, respectively.

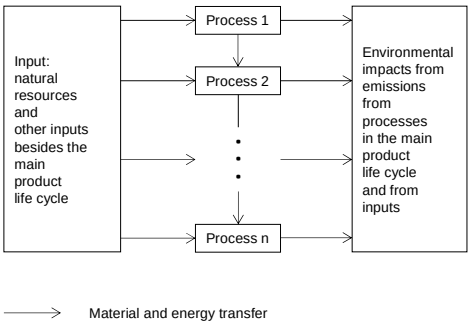


Figure 3.1a: Simplified conceptual presentation of an LCA

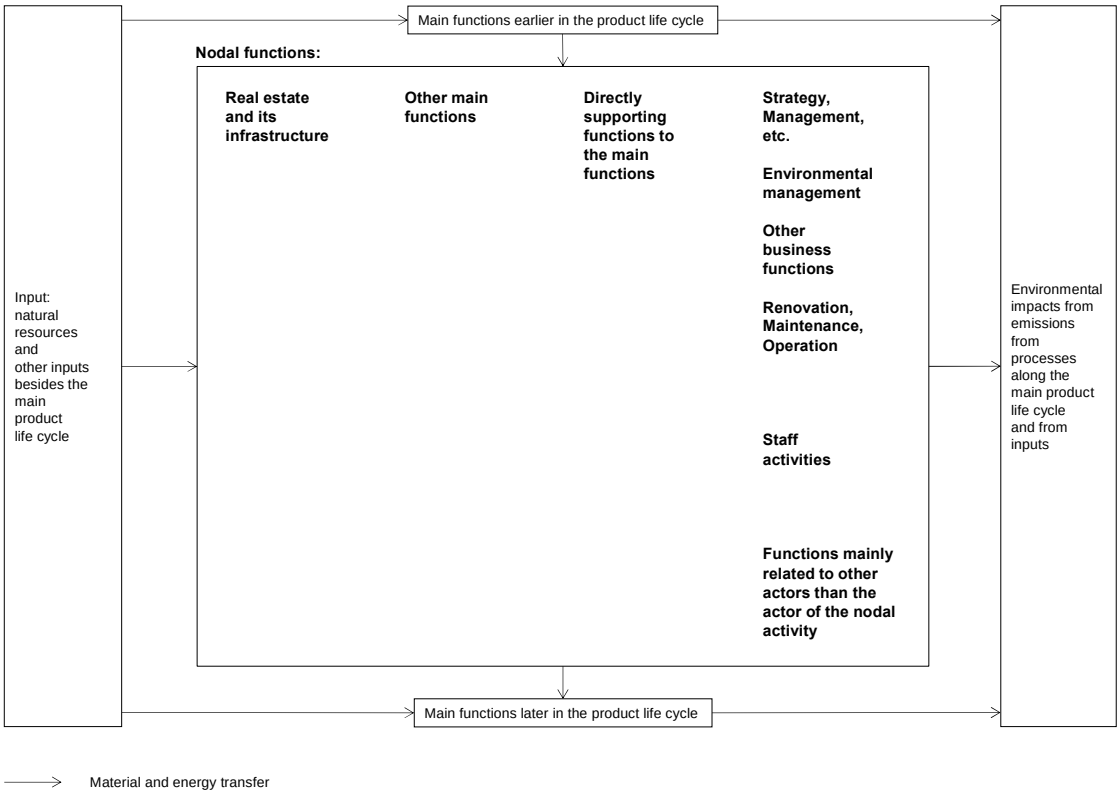


Figure 3.1b: Conceptual presentation of LCA based indicated environmentally significant organisational practices in this report

4. BOWLING (BASED ON TEST CASE 1)

In this chapter, we focus on the in the here reported on project identified organisational practices of indicated product life cycle environmental significance for the service bowling and traced from nodal sites of three bowling halls in Gothenburg, Sweden. The LCA based environmental impacts of bowling have been indicated to be of a moderate magnitude in comparison to those of other sectors of the economy (cf. Ukidwe, 2005, pp. 132, 221, 230–262). In addition, a considerable amount of time is put into performing the activity of bowling in Sweden[1] (cf. SBHF, 2012).

4.1. Study objects

4.1.1. Selection of study objects

The selection of the study objects in the bowling test case, and the approach to how they were studied, have been based on a few delimitations. First, only leisure bowling activities open to the public have been considered, and thus bowling played by amateurs organised in associations has not been covered although it is performed at a considerable degree in Sweden (cf. SBHF, 2012). This delimitation was relevant since it facilitated studies through visits as a customer, and made the study easier to perform by not covering activities that differ regarding for example how they are scheduled and how they utilise other functions at the bowling halls (cf. Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010). Second, the type of bowling that is labelled 'virtual bowling' has not been included. In virtual bowling, bowling balls are rolled half of the length of a standard bowling lane and then a computer calculates its trajectory on the second half of the lane and the outcome of the throw. Virtual bowling has not been included since it in some aspects is a different type of activity, and since it at the time of the project was played to a considerable smaller degree in Sweden than *standard bowling*, based on a sample of the number of publicly listed virtual bowling halls (Eniro, 2012). Third, and finally, delimitations have been made based on the presence of and properties of a type of standard bowling that is labelled *disco bowling*. This form of bowling sometimes requires that the players are adults – because of a combination of selling alcohol during these hours and targeting an adult customer group. (cf.

[1] In total 226 bowling halls were associated with the sector organisation Sveriges Bowlinghallars Förbund (in English: The Swedish Association for Bowling Halls) as of 5 May 2012 (SBHF, 2012). Since the halls in Gothenburg found in this list align closely with the bowling halls listed in the, with it contemporary, Swedish yellow pages (Eniro, 2012), this figure is assumed to well represent the by then total number of bowling halls in Sweden.

Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010.) Therefore, the bowling test case was delimited to bowling performed by adults.

Three bowling halls that at the time of carrying out the bowling test case study (2010) were located in different peripheral areas of the city centre of Gothenburg, Sweden, were selected as nodal sites in this test case. At the time of the study, they all offered standard bowling for the public. In these services, they supplied rental balls and shoes for the customers to use.

The functional unit in the bowling test case has been based both on the mentioned characteristics of disco bowling, and on time aspects of the bowling activity, and has been chosen to be *one adult's public bowling occasion*. Regarding the time aspect, this takes into account that the time spent bowling might depend on the offering of other services at the hall.

4.1.2. Data collection

The bowling test case is based on visits to the three covered bowling halls, the web sites of these halls, bowling equipment suppliers and sector organisations, and literature. Initial studies of the number of and types of bowling halls in Gothenburg, Sweden, were performed using general company directories (cf. Eniro, 2012) and web sites of a wider selection of halls than the three ones further studied. Based on this information, three halls suitable for comparison were selected. The visits were also preceded by studies of web pages of sector organisations and suppliers, and of research on environmental impacts of bowling and on other cultural activities. The visits were used not only for the study of organisational practices but also for the LCA based overview since very little information on environmental impacts could be found in existing literature and since the web pages of the three studied halls contained very little of this type of information.

4.1.3. About the three sub-cases

The three bowling halls that the bowling test case was based on studies of were Star, Majorna bowling, and Valhalla Bowling (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010). Of these, Valhalla Bowling ceased to be in operation during the study period of 2010–2013 (Valhalla Bowling, visit 2010, visit 2012). All of the three halls were medium sized bowling centres. Regarding the general characteristics of the three halls and the services provided at them, the Star hall was an entertainment centre hosting other activities than bowling as well and for relatively high prices. At the Valhalla Bowling hall, basic and relatively cheap bowling services and attracted youths to a high degree were provided. Finally, the general characteristics of the Majorna bowling hall lay approximately in the middle between the characteristics of those of the Star hall and the Valhalla Bowling hall. Further specification of, among other, opening hours and food and beverage services provided, for the three bowling halls are presented in Table 4.1, further on in this sub-sub-chapter.

Table 4.1: Overview of general characteristics of the three bowling services

	Star	Majorna bowling	Valhalla Bowling
Operational status	-	-	Closed down, as of 7 June 2012 (Valhalla Bowling, visit 2012)
Prices and opening hours	180–340 SEK/person/hour (discounts for youths, students, families and seniors) (Star, 2012b)	130–320 SEK/person/55 minutes (discounts for families, youths and children) (Majorna bowling, 2012f)	Lower prices than Star and Majorna bowling (Valhalla Bowling, visit 2010)
	Open from around noon until around midnight Monday–Saturday (Star, 2012b, e)	Open from around noon until around midnight (Majorna bowling, 2012f)	Open from around noon until late evening (Valhalla Bowling, visit 2010)
Additional general characteristics	Moderately simple web page dedicated to describing their offers (Star, 2012b, e)	Moderately simple web page dedicated to describing their offers (Majorna bowling, 2012d)	No web page besides being listed on the web through yellow pages and similar, as of 15 April 2010
	Offered food and alcohol in their restaurant and bar next to the lanes (Star, 2012a, d)	Offered food and alcohol in their restaurant and bar next to the lanes (Majorna bowling, 2012a, d, e)	Had a small kiosk, but otherwise no additional offers (Valhalla Bowling, visit 2010)
	Offered other indoor leisure activities such as multi-person competitive car racing simulators (Star, 2012e)	-	-
	Two specific offers were conferences and larger groups (Star, 2012c, e)	Two specific offers were children's parties and league playing for players with different levels of experience (Majorna bowling, 2012b, c, d)	Customers were below the age of 18 to a large extent (Valhalla Bowling, visit 2010)

4.2. Life cycle assessment screening

Very few investigations had been made into the environmental impacts from bowling at the time of the study of the bowling test case. However, a US study shows that bowling halls in the USA, from an exergy input-output LCA based perspective and including ecosystem issues caused

moderate environmental impacts compared to other US sectors (Ukidwe, 2005, pp. 132, 221, 230–262).

Based on the information provided by bowling service providers and the visits, a few potentially substantially environmentally impacting functions have been outlined. These functions are in the following presented in the four groups outlined in the previous chapter: building shell and building infrastructure, lane equipment as other main functions, directly support to the main functions by surrounding functions, and business, lane maintenance, staff transports and customer transports. These functions, to some extent, cover activities at the halls that were not directly prerequisites for the bowling activities. These include additional games and other similar activities, and food and beverage services. (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010.) Regarding these food and beverage services, they seemed to be designed to be combined directly with the bowling activities (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010) and they have therefore been taken into account. Regarding the other to bowling additional activities, these have been taken into account when performed as consequences of bowling activities, but not when performed solely on their own. The four groups of functions are also part of the visualisation in Figure 4.1, at the end of this sub-chapter.

4.2.1. Building shell and building infrastructure

A few different indicated product life cycle environmentally impacting bowling functions have been outlined for building shell and building infrastructure in the bowling test case. For the shells, different properties of both new construction, and reconstruction, have been covered. For the infrastructure, temperature control, humidity control and ventilation, as well as lighting, have been included. Regarding the shells, new construction and reconstruction generally result in substantial life cycle environmental impacts, such as from cement production, and these may be larger than average construction in bowling halls for several reasons. Space is required particularly for bowling lanes, and due to often not fully utilised facilities (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010). In addition, specific construction measure may be needed because of point loads from equipment, customers and vibration, as well as to provide soundproofing against noise (cf. Brunswick, 2012d).

Regarding building interior, temperature control, humidity control and ventilation seem to be of environmental relevance both for indoor commercial activities in general and for bowling in particular. The energy needed for these functions is one main cause of potentially substantial environmental impacts. The size of these impacts may be particularly high compared to other indoor environments due to the combination of several factors. These include the need for customer comfort over periods of several hours (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010), and sensitive equipment (cf. Brunswick, 2012d). They also include

varying customer load, and the relatively large air volumes related to the above mentioned lane size in the premises (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010).

Further, lighting is generally linked to environmentally impacts, through energy supply, and a specific characteristic applies for bowling halls. Different coloured lighting for the service disco bowling might result in particular environmental effects. (cf. Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010.)

4.2.2. Lane equipment

Regarding the bowling lanes, these and the equipment and machinery used at these lanes consist of several parts. From an LCA perspective, construction is potentially environmentally significant. This applies to lanes, position support for lanes, bowling balls, pins, and machinery for handling pins and balls. For the construction of this equipment the materials needed, production processes, and end-of-life handling are of seeming interest (cf., e.g., Brunswick, 2012b, c; QubicaAMF, 2011c, d; VBS Bowling, 2012a).

4.2.3. Surrounding functions

In this section, additional functions closely related to the bowling in the halls and visible to customers are covered. These include IT-systems for bowling results and operational management, rental shoes including odour protection, furniture, decoration and music; food, beverages and games and similar other additional services, payment, clothing storage and restrooms, as well as cleaning.

Regarding results systems and operational management, a range of systems based on IT and multimedia are available for and used in bowling halls, and contribute to potentially substantial environmental impacts. Result systems provide through visual displays bowling results information to customers, but also entertainment and advertising. Operational management systems are used for control of the lanes machinery and tracking of customers. (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010.) Tracking of customers cover planning of lanes to use, control of time-based activities, and the handling of profiles on types of customers (cf., e.g., Brunswick, 2012a; QubicaAMF, 2012). The environmental impacts cover those related to the electricity use of the equipment, as well as for the IT systems environmental impacts from natural resource use, and energy supply and waste treatment along the product life cycles of the systems.

Regarding shoes, all of the in the bowling test case visited bowling services provided rental shoes for their customers (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010). Product life cycle environmental impacts occur from shoes production and disposal, and two potentially environmentally affecting shoes odour protection methods were at bowling halls in general in use at the time of the study of this test case. The first of these methods is the application of a type of deodorant spray where production, use and waste management regarding

for example toxicity of chemical spray ingredients may be of significant environmental importance. The other method is the use of disposable socks to wear on top of regular socks where substantial amounts of materials may be a waste treatment problem and which might impact the environment significantly through for example materials and energy used for their production. (cf., e.g., Bowltech Sweden, 2008b; QubicaAMF, 2011e). No disposable socks were seen during the visits in the bowling test case (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010).

Regarding furniture, decoration and music, they are potentially environmentally significant due to intensive use (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010) combined with environmental impacts as such from their product life cycles. Regarding furniture, the repeated times customers sit down during the bowling activity puts special requirements on durability (e.g., QubicaAMF, 2011a). Decoration here refers to masking systems of large panels and large video screens, as well as decorative lighting. The masking systems are fitted particularly above the far end of bowling lanes and are thus a focus point for bowling customers (e.g., QubicaAMF, 2011b, and f). For the panels, considerable amounts of paint may be used and result in potential environmental issues related to chemical contents and production. For video masking screens, large and specialised screens are required, with associated environmental impacts from these IT-systems regarding natural resource use, energy supply and waste treatment along the product life cycles of the systems. Decorative lighting was particularly used in two of the visited bowling halls for disco bowling with violet and fluorescent light, and specialised lighting devices may here be of environmental concern. The use of music is also a characteristic of disco bowling, and it can be noted that it was played at high volumes at the two in the bowling test case visited halls providing disco bowling. (Majorna bowling, visit 2010; Star, visit 2010.)

Both provision of food and beverages, and to bowling additional games and similar activities at bowling halls may result in substantial environmental impacts or substantially different impacts than their alternatives. Regarding food and beverage, restaurants, bars and other food and drinking services at bowling halls potentially contribute to higher environmental impacts than the alternatives available for food and beverage consumption. (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010.) Through a service LCA on opera and theatre performances, environmental impact were calculated for an in-house restaurant at the premises of an opera (Tengström and Izurieta, 2010), and these figures can be used to give some indications for customers' food and beverage consumption at bowling halls since both are leisure services provided repeatedly at a fixed location. The opera restaurant was found to contribute to significant parts of the opera performance's overall eutrophication (around 15%, mainly from production of meat) and water use impacts, as well as to minor parts of the acidification (around 8%) and global warming (around 2%) impacts (Tengström and Izurieta, 2010, pp. 41–42, 44–46, 50–51). However, in their study, impacts from energy supply, water supply and wastewater treatment

were not divided between the opera performance and its surrounding activities, and inclusion of these may result in larger environmental impact shares attributable to the restaurant. Further, visitors' food choice outside of the opera premises – impacts from eating at home or at a nearby restaurant – were not included in the study. Regarding additional games and similar activities, the presence of these at bowling halls may encourage bowlers to increase their consumption of these services as well. This may lead to additional environmental impacts, but also to decreased environmental impacts if they replace the bowling activity and at the same time result in lower environmental impacts per relevant functional unit than the bowling.

Regarding payment, clothing storage and restrooms, the space needed for these put result in potentially substantial environmental impacts via heating, lighting and cleaning. In addition, IT systems result in several environmental impacts regarding payment handling. Finally, potentially substantial environmental impact may result from water supply and wastewater treatment associated to the customer restrooms of bowling halls. (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010.)

Regarding cleaning, it is generally linked to environmentally impacts through chemicals, and a specific characteristic apply for bowling halls. Special cleaning products are produced for the cleaning of bowling lanes (e.g., Bowltech Sweden, 2008a).

4.2.4. Additional functions

In this sub-sub-chapter, we present additional functions at or connected to bowling halls that result in indicated product life cycle environmental impacts. These functions include the business functions offices, staff premises and marketing, lane maintenance, staff transports, and customer transports.

Offices for running the bowling hall services as well as staff premises such as lunchrooms and restrooms contribute to environmental impacts. The impacts are related to heating of the spaces, materials use, cleaning, fresh water supply and wastewater treatment. Product life cycle environmental impacts from materials use for the services opera and theatre stage performances were presented as being low or very low for offices. For a theatre play, it accounted for 1.5% of the eutrophication potential, and for 0.77% of the acidification potential. It represented less than 0.3% for eutrophication and acidification potentials for an opera performance, respectively, and for the global warming potential and resource use, respectively, for each of the theatre play and the opera performance. However, these figures for the environmental impacts of the offices did not include impacts from computers and other impacting functions besides paper. (Tengström and Izurieta, 2010, pp. 37–39, 44–46, Appendixes 7–8, 12–13.)

Marketing results in environmental impacts through different activities. The product life cycle environmental impacts shares resulting from paper for products such as programme catalogues have been presented as representing only small parts of the impacts for an opera performance. They represented for eutrophication 1.3%, for acidification 0.6%, and for resource use and global

warming impact very small parts (less than 0.2% for each of these) (Tengström and Izurieta, 2010, pp. 37–39, 44–46, Appendixes 8, 13). However, this may not be as applicable to bowling services, where other marketing activities such as newspaper advertising and web pages might be of significance.

From an LCA perspective, maintenance of bowling lanes can be potentially environmentally significant. For friction control in machinery, oil is used, with associated environmental aspects of its production and end-of-life handling. Further, repairs with associated equipment, and parts and sub-parts replacements are needed unless the entire equipment is replaced. Finally, the lanes are conditioned and their surface layers are adjusted. In addition to the production and handling of conditioners, special machinery is used for carrying these tasks out. (cf., e.g., Kegel, 2012a, b, c; VBS Bowling, 2012b.)

Transports of staff have been presented as accounting for relatively large shares of product life cycle environmental impacts for other leisure activities, but the conditions for the staff transports connected to these activities seem to be substantially different from those connected to bowling halls. For a theatre stage performance, 17% of the product life cycle global warming potential has been presented as originating from staff transports while the same figure for an opera stage performance has been presented as 8.2% (Tengström and Izurieta, 2010, pp. 36, 44, Appendixes 12–13). However, the larger number of bowling halls than opera stages and larger theatres in Sweden might result in shorter distances needed for employees of bowling halls to travel. In addition, potentially less specialised employee functions at bowling halls might result in shorter commuting ranges for bowling hall employees. (cf., e.g., Majorna bowling, visit 2010; Star, visit 2010; Tengström and Izurieta, 2010; Valhalla Bowling, visit 2010.)

Customer transportation has been found to account for larger shares of the product life cycle environmental impacts of some leisure services, and ought therefore to be considered. For a rock concert, more than three quarters of the carbon dioxide (CO_2) product life cycle emissions have been presented as stemming from customer transport (Wallin, 2008, cited in Brunklaus, 2009b). For a football event, customer transportation was presented as resulting in the largest of the different product life cycle environmental impacts covered (Pladerer, 2009, cited in Brunklaus, 2009b). For a theatre and an opera stage performance, customer transports have been presented as accounting for 36% and 29% of total product life cycle global warming impacts, respectively (Tengström and Izurieta, 2010, pp. 29, 44, Appendixes 12–13). Since bowling halls are comparably common in Sweden, the average distance of customer transportation needed is likely shorter for bowling events than for these other activities (cf., e.g., Majorna bowling, visit 2010; Pladerer, 2009, cited in Brunklaus, 2009b; Star, visit 2010; Tengström and Izurieta, 2010; Valhalla Bowling, visit 2010; Wallin, 2008, cited in Brunklaus, 2009b). Thus, they might result in customer transports contributing to smaller shares of the product life cycle environmental impacts for bowling than for these other here mentioned types of events.

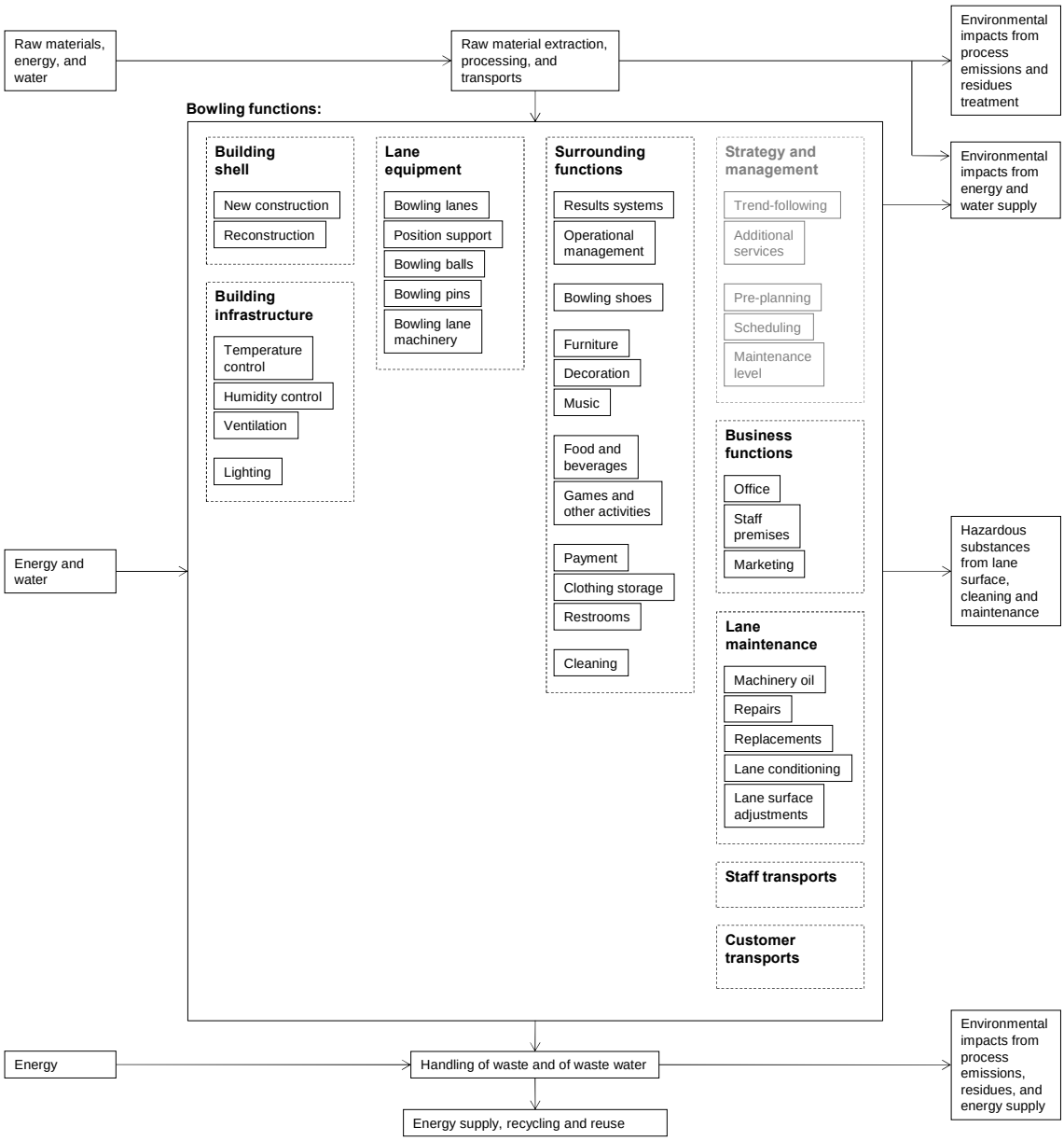


Figure 4.1: Overview of screened indicated product life cycle environmentally significant functions for the three bowling services. Directly through material and energy connections environmentally contributing functions in black, and indirectly contributing ones in grey.

4.3. Socio-material points of interaction at the product life cycles

The socio-material interactions at the product life cycles via which organisational practices have been indicated to cause considerable environmental consequences in the bowling test case are connected to overall planning (A), types of services provided (B), and premises maintenance and planning (C). The indicated environmental consequences of practices traced from these interactions at the studied bowling halls are developed in the subsequent three sub-chapters.

4.4. Overall planning (A)

The overall planning, including management, of bowling halls have been found to be of potential environmental significance particularly since it seems to contribute to environmental impacts via many of the different functions of bowling services. In the bowling test case, this has been related to the potential ceasing of business, to the level of trend-following regarding equipment, and to the influence of lunch provision on fill rates, respectively.

The ceasing of business was observed for one of the three bowling halls covered in the bowling test case (Valhalla Bowling) during the time of its study. Such termination of operation might result in particularly high environmental impacts because of heating of large unused premises, difficulty to recycle the specialised interiors and equipment, and special properties of the layout of and foundation for the premises. (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010.)

In addition, the ceasing of business might be related to not following trends in the bowling sector and with these associated environmental impacts. It was also clear from the visits that Valhalla Bowling to a lesser degree followed new trends of for example in-house restaurants and disco bowling than particularly Star. (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010.)

Regarding fill rates, this here refers to how efficiently the space of both customer and staff areas are utilised at bowling hall premises. Among other, temperature control, moisture control, and cleaning are needed for an area to some degree also when it is not used. In the bowling test case, it was found that the halls of Star and Majorna bowling had the same amounts of opening hours weekly, but that Star contrary to Majorna bowling provided lunch and marketed lunch bowling as a distinct concept (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010). Thereby, the fill rates particularly during lunch, but also on average, might be higher for Star, both for the bowling area and for the restaurant area.

See Table 4.2 and Figure 4.2, further on in this sub-chapter, for summaries of the described types of overall planning and their indicated environmental significance.

Table 4.2: Overall planning (A)

	Star	Majorna bowling	Valhalla Bowling
Ceasing of business that cause impacts from for example heating of unused premises	-	-	Business ceased during the study of the bowling test case
Following trends for the equipment, which may result in impacts from advanced and often replaced equipment, but also reduce risk of ceasing of business	Following trends to a high degree	Following trends to a moderate degree	Following trends to a low degree
Lunch provided at in-house restaurant, and which might increase average utilisation of the premises	Yes	-	-
➔ A more detailed study of the fate of the premises were business ceased, of the equipment's effect on customers and its environmental impacts and of the utilisation rates between halls where lunch is served or not may reveal environmental impacts differences between the three studied bowling services.			

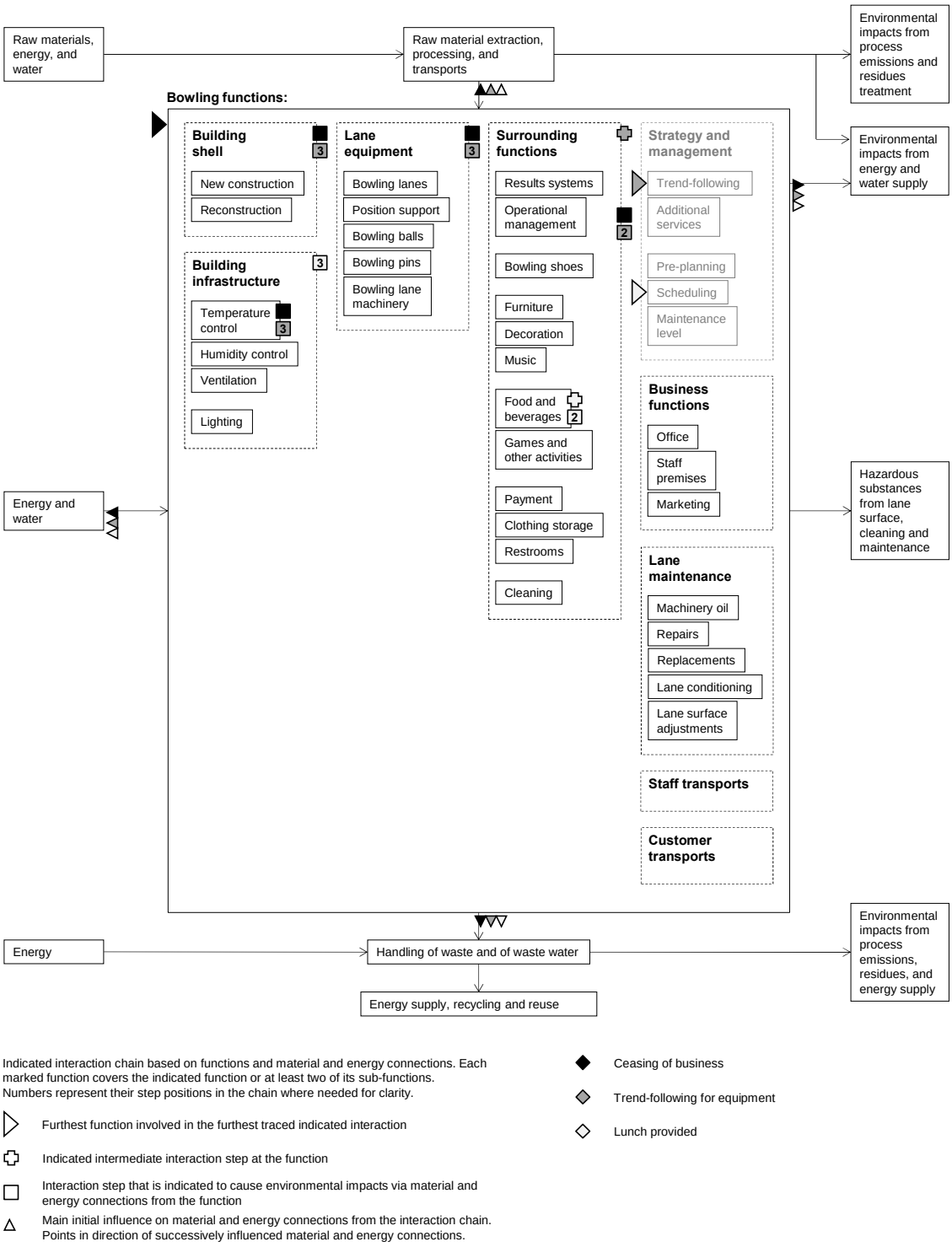


Figure 4.2: Main covered interaction paths connected to the overall planning that is indicated to influence product life cycle environmental performance

4.5. Types of services provided (B)

Several to bowling complementary services at the halls covered in the bowling test case were found to be of potential environmental significance. Of these, disco bowling, in-house restaurants,

and additional games and similar activities are discussed further here due to their variations' seeming influence on environmental impacts. Disco bowling is characterised by loud music and dim lighting (fluorescent). The amount of active bowling time per person and bowling occasion may vary between regular bowling and disco bowling, due to higher degrees of focussing on other activities such as listening to music and bar services than during non-disco bowling. In addition, environmental impacts may be influenced due to the music, lighting and other decoration. It could be, for example, wear from a combination of not well visible lanes in the dimmed and violet light that is common and the loud music that also might lead to less ability to hinder the heavy bowling balls from damaging the lanes. At the three halls here studied, disco bowling was offered during all opening hours at Star, and it was provided during evenings and thereby during parts of the opening hours of Majorna bowling. At Valhalla Bowling, it was not offered. (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010.)

The presence of in-house restaurants and bars at bowling halls may, as discussed previously in this chapter, result in changed environmental impacts depending on the alternative options for food and drinks that the customer would have chosen otherwise, but may have other environmentally significant effects as well. As for disco bowling, the time spent performing the actual bowling activity may be influenced by both an in-house restaurant and an in-house bar. In-house restaurants and bars were in the bowling test case found at Majorna bowling and Star, while Valhalla Bowling had an in-house kiosk (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010). It can also be noted that Majorna bowling was found to offer a combined dinner and bowling activity where the bowling time is set to one hour and 25 minutes compared to their standard bowling time unit of 55 minutes (Majorna bowling, 2012e, and f).

Regarding additional games and similar activities on the bowling premises, it might, as mentioned, be encouraged to perform them in addition to bowling due to them being co-located. The presence of such games was only found at Star among the three halls covered in the bowling test case (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010). At Star, the bowling lanes were located on the ground floor, while the first floor was largely dedicated to different types of games, such as multi-person racing simulators and dart (Star, visit 2010).

See Table 4.3 and Figure 4.3, further on in this sub-chapter, for summaries of the described types of additional services and their indicated environmental significance.

Table 4.3: Types of services provided (B)

	Star	Majorna bowling	Valhalla Bowling
Disco bowling's potential influence on environmental impacts from bowling time, wear, and decoration	Disco bowling only.	Disco bowling in the evenings (for some hours offered for all ages). Regular bowling during daytime.	-
Restaurants' and bars' potential to influence environmental impacts by replacing alternatives and influencing bowling time	An in-house restaurant also serving lunch, and an in-house bar.	An in-house restaurant not serving lunch, and an in-house bar. Offers a combined dinner and a 1 hour and 25 minutes bowling compared to standard slots of 55 minutes	In-house kiosk.
Additional games and similar activities potentially encourage more but also potentially less impacting consumption	Additional games and similar activities on the floor above the bowling lanes.	-	-
➔ A more detailed study of the effects of disco bowling, of the effects of restaurants and bars compared to alternatives and on bowling time, and of effects of additional games and similar services may reveal environmental differences between the three studied bowling services.			

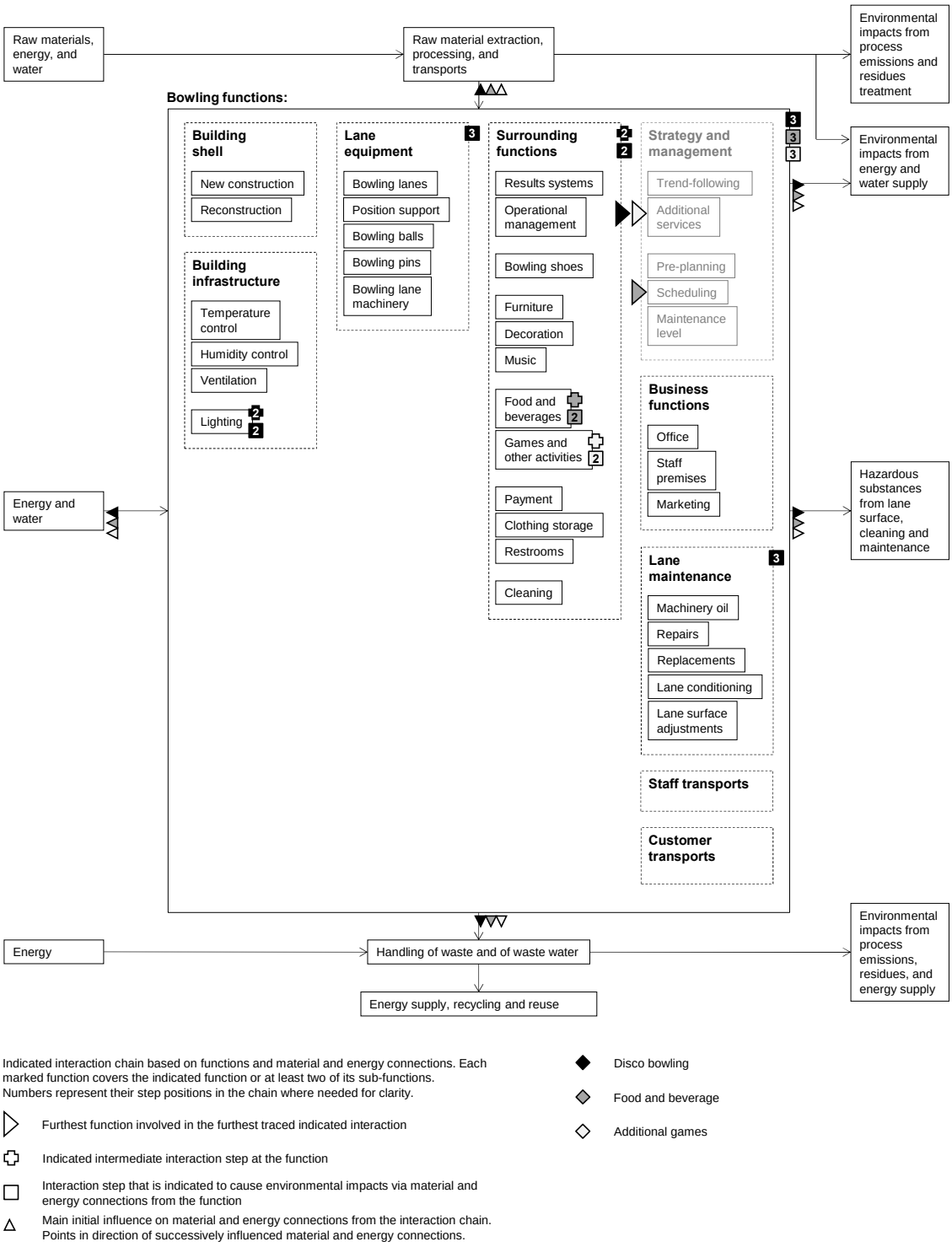


Figure 4.3: Main covered interaction paths connected to the additional services that are indicated to influence product life cycle environmental performance

4.6. Premises maintenance and planning (C)

Some premises planning and maintenance parameters of bowling halls may have significant environmental impacts and affect both the equipment in the halls and customer satisfaction. In

the bowling test case, this was indicated for lane surface maintenance, and temperature and moisture control. A bowling lane is covered by a surface that needs to be both smooth and protect the material below it. Well-planned maintenance is a necessity in order for the heavy bowling balls not to destroy the surface and cause large damages that need repair. It might also be of importance for customer satisfaction, and thereby the overall possibility of the hall business to continue. Differences regarding the maintenance of the lanes were seen between the three halls. The lanes at Star were most well maintained, Valhalla Bowling least well, and Majorna bowling was found approximately in the middle between these two regarding this aspect. (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010.)

The air temperature and humidity also need to be held within certain ranges for the bowling equipment to maintain a long lifespan. Therefore, it is of potentially significant environmental importance to control these parameters well. (Brunswick, 2012d.) Connected to this, a wise planning of the facilities interior and its access to areas with other levels of temperature and moisture might be vital. The temperature and moisture control is also of importance for the customer satisfaction and the related aspect of the bowling hall staying in business. The three halls covered in the bowling test case might have had considerably different needs of temperature and moisture control due to varying access paths from the often, in Gothenburg, from indoor conditions differing temperature and moisture of the outdoor environment to the halls. These paths were found to lead directly from the street at Star, through a staircase spanning more than one storey at Majorna bowling, and via a corridor at Valhalla Bowling. (Majorna bowling, visit 2010; Star, visit 2010; Valhalla Bowling, visit 2010.)

See Table 4.4 and Figure 4.4, further on in sub-chapter, for summaries of the here covered maintenance and planning practices, and their indicated environmental significance.

Table 4.4: Premises maintenance and planning (C)

	Star	Majorna bowling	Valhalla Bowling
More lane maintenance increases environmental impacts from maintenance products, but lowers the risk of break-down, and may increase customer satisfaction and thereby the possibility to continue business	The lanes were well maintained.	The lanes were relatively well maintained.	The lanes were in need of maintenance.
Outdoor climate kept at distance for lowering indoor adjustment needs for keeping equipment from harm and keeping customers satisfied	Location well below the entrance from the street.	Entrance directly from the street.	Access of premises through a corridor.
➔ A more detailed study of environmental impacts from lane maintenance products and associated avoided lane wear and of climate control needs and their environmental performances may reveal that environmental impacts differ between the three studied bowling services.			

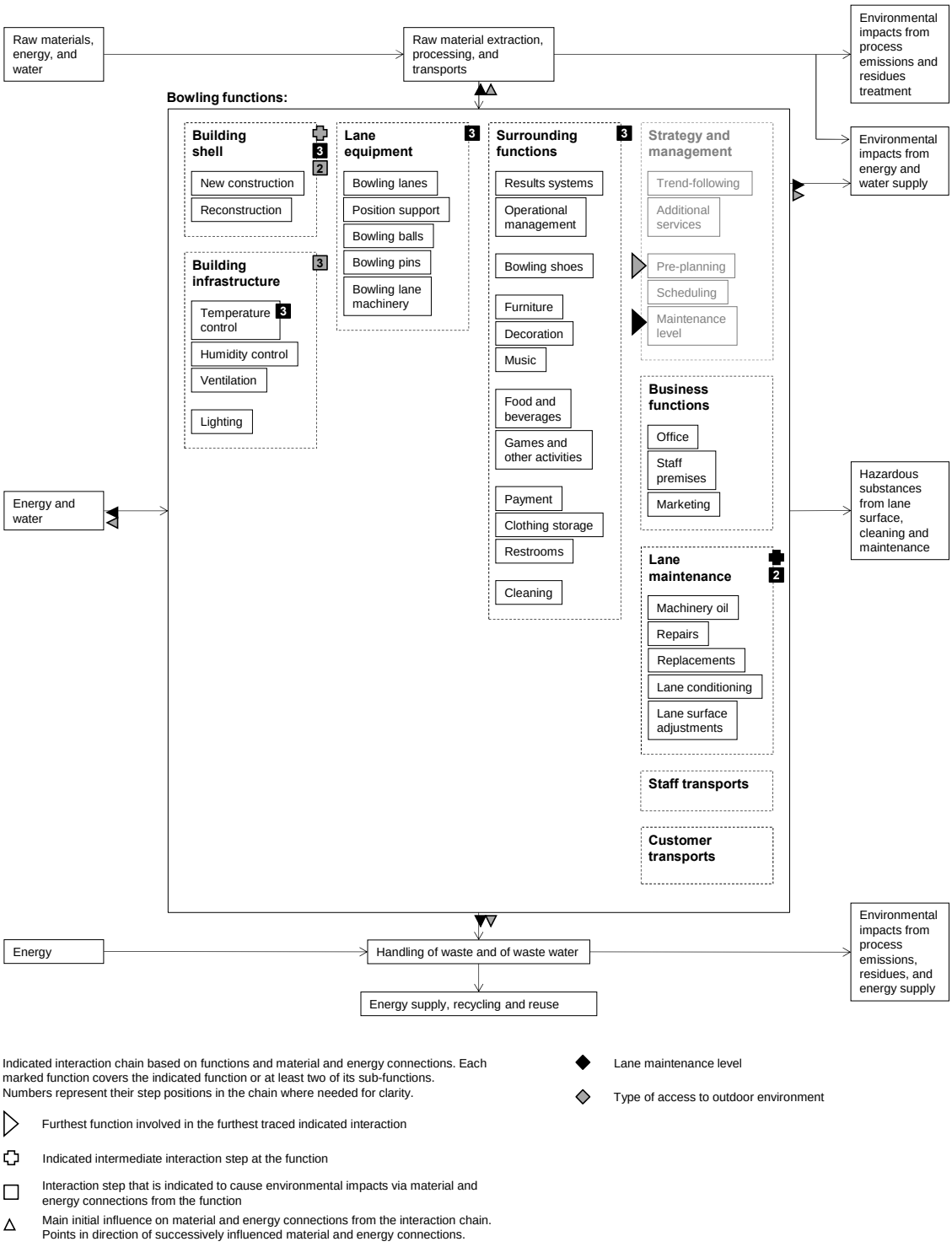


Figure 4.4: Main covered interaction paths connected to the premises maintenance and planning that is indicated to influence product life cycle environmental performance

4.7. Analysis and summary of the test case

In this sub-chapter, we present a combination of the outcome of an analysis of and a summary of the previously in this chapter presented eight bowling service practices and their indicated

potentially significant influence on the product life cycle environmental impacts. These environmental impacts were indicated to be moderate from the perspective of environmentally harmful emission and resource use occurring in the Western world. The degree of certainty of environmental significance of each of these practices have been found to lie between moderate and low, since the bowling test case mainly is based on a few visits as customer to bowling halls and a mainly qualitative LCA basis due to lack of previous bowling LCA studies or similar studies. Further, each of the eight practices seems to be connected to each of the other practices in not necessarily discernible ways, mainly either weakly or moderately. This is outlined for the respective connections in Table 4.5, further on in this sub-chapter. In addition, the practices were found to be dependent on the service characteristics of considerable requirements regarding indoor space, strong building foundation, and air conditions. Further, the practices seem to include coverage of nine seemingly generic issues that might to be of environmental relevance for many other activities in society and which seem to cover the main findings for all of the eight practices identified. These nine are services that are ceasing of business, trend following, environmental impact of a function in relation to other by it influenced or to it alternative functions, offers that are provided in addition to the core offer, fill rates, scheduling, maintenance level, sudden break-down unless sufficient maintenance, premises layout. The taken together seeming importance of each of these for understanding each of the eight practices is to considerable degrees either moderate, high, or very high and to a small degree none or low. This is outlined per issue and per practice in Table 4.6, further on in this sub-chapter.

Table 4.5: Indicated strengths of connections between the covered bowling services practices

Indicated environmentally significant practice at the bowling halls. A: Overall planning B: Types of services provided C: Premises maintenance and planning	Strength of connection between the practice and the other practices. 0 = no or very weak, 1 = weak, 2 = moderate, 3 = strong							
	A.1	A.2	A.3	B.1	B.2	B.3	C.1	C.2
A.1 Ceasing of business, or not: Its environmental impacts from equipment, unused premises and special building properties		2	2	2	2	2	2	1
A.2 Equipment trend following degree: Influences environmental impacts from new equipment and potentially from decreased risk of ceasing of business			1	2	1	1	1	1
A.3 Lunch provision or not: Its effect on fill rates and the effect of the lunch service as such				1	3	1	1	1
B.1 Disco bowling degree: Its potential impact on bowling time, wear, and decoration					2	2	2	1
B.2 Restaurants and bars degrees: Their potential to influence environmental impacts by replacing alternatives and influencing bowling time						2	1	1
B.3 Additional games and similar activities degrees: Their potential to encourage more or less impacting consumption							1	1
C.1 More lane maintenance degree: Increases environmental impacts from maintenance products, but lowers the risk of break-down, and may increase customer satisfaction and thereby the possibility to continue business								2
C.2 Outdoor climate kept at distance degree: For lowering indoor adjustment needs for keeping equipment from harm, and keeping customers satisfied and thereby the possibility to continue business								

Table 4.6: Seeming generic issues and their indicated importance for explaining the covered bowling services practices

Seeming generic issues	Indicated importance for explaining the practices. 0 = no or low, 1 = moderate, 2 = high, 3 = very high							
	A.1	A.2	A.3	B.1	B.2	B.3	C.1	C.2
Ceasing of business	3	2	1	2	2	1	2	2
Trend following	2	3	1	3	2	1	0	2
Environmental impact of a function in relation to other by it influenced or to it alternative functions	2	2	3	2	3	3	3	3
Offers that are provided in addition to the core offer	2	0	3	3	3	3	0	0
Fill rates	2	2	3	2	2	2	2	2
Scheduling	1	1	3	1	2	1	1	1
Maintenance level	2	2	1	2	1	1	3	1
Sudden break-down unless sufficient maintenance	1	1	1	1	1	1	2	1
Premises layout	1	1	1	1	1	1	1	3

Further, it seems for most of the eight practices not clear whether they in a certain state would lead to increased, decreased, or similar product life cycle environmental impacts. Therefore, it seems not possible, based only on the bowling test case, to rank the three bowling services studied regarding environmental performance per bowling occasion for adult persons provided – a more detailed study is necessary for that.

Nevertheless, the presentation based on the screening seems to show that the environmental performance is not easily deduced from the material and energy input to the bowling halls and the number of bowling hours, as would be the procedure in standard LCA. Even if no direct quantitative environmental differences were possible and feasible to present, the screening has *at least* shown that the bowling halls operated with different business approaches and that the environmental performances seemed to depend on an intricate interplay of organisational practices with technology and material and energy. This includes, among other:

- Ceasing of business and its environmental impact through among other heating of unused premises
- Lunch provision or not and its environmental impacts compared to those of alternative lunch options and its effect on fill rates

- Additional games and similar activities degrees, and their potential to encourage consumption with a larger or smaller environmental impact

Further, these and other of the identified practices seem to have been considerably dependent on each other. A thorough nodal LCA organisation study might result in an understanding of how some of these and other practices are related and their magnitudes of influence on environmental performance. A reason why it may not be the result is the seeming intricate relations between the practices for a very large share of them. Based on the list just prior to this paragraph, for example, ceasing of business seemingly depended on among other both lunch provision and additional games and similar activities degrees. These causes and effects likely to a moderate to high degree were difficult to discern due to many highly intricately involved causes, additional impacts on environmental performance of these, and that case studies probably only could cover certain specific modes of these practices. On the other hand, such a result seems in itself to be moderately to highly relevant for pointing to the usefulness of searching for complementing approaches to direct changes to the organising for considerably lowering the environmental impacts caused by environmentally ineffective organising. Finally, the ratio between the occurrence of results useful for concrete actions and this pointing towards complementing approaches seems for bowling product life cycle environmental performances with bowling halls in Sweden as nodes to be moderately difficult to predict and the taken together gain of these results have been indicated to be moderate compared to using a screening approach. The components and overall findings on this reasoning on choosing between a screening and a thorough nodal LCA organisation study for this product type and this type of nodes is presented in Table 4.7, further on in this sub-chapter.

Table 4.7: Overview of findings from reasoning on differences in usefulness between a screening and a thorough nodal LCA organisation study for bowling product life cycle environmental performances with bowling halls in Sweden as nodes

Useful findings from the screening nodal LCA organisation study – summary		Business model differences seem to have influenced environmental performance Identified intricate interplay between organising, technology, and materials and energy processes
Seeming gain of performing instead of screening a thorough nodal LCA organisation study	Environmental performance: Overall	Moderate
	Environmental performance: Per part of the system	Large to moderate
	Environmental performance: Over time	Moderate
	Organisational study	Moderate to large
	Producing a basis for carrying out concrete actions	Small to moderate
	Taken together: Magnitude of gain and its predictability based on the screening	Moderate gain Moderate predictability
	Taken together: Types of gain and their predictability based on the screening	Moderately to largely pointing to a need for complementing alternative approaches Moderately to little producing a basis for carrying out concrete actions Moderate to low predictability

5. BREAD PRODUCED IN BAKERIES (BASED ON TEST CASE 2)

In this chapter, we focus on the in the here reported on project identified organisational practices of indicated product life cycle environmental significance for the physical commodity soft bread produced in bakeries and traced from nodal sites of three bakeries in Gothenburg and Malmö, Sweden. Bread produced in bakeries is a product that in Sweden seems to contribute to non-negligible product life cycle environmental impacts (cf. Andersson and Ohlsson, 1999; FCCC, 2013, p. 14; Nationalencyklopedin, 2001; SCB, 2013). In addition, it has already been indicated to have varying life cycle environmental impacts depending on an organisational factor – the scale of business of the bakeries (Andersson and Ohlsson, 1999).

5.1. Study objects

5.1.1. Selection of study objects

Three bakeries in the cities Gothenburg and Malmö, both in Sweden, were selected as nodal sites in the bread test case. At the time of the study, they operated at different scales of business regarding their soft bread production. Regarding their products, all of them produced several types of soft food bread products. They also, to different degrees, produced *sweet baked goods*, such as pastries and sweetened buns. (Adem, per. comm. 2010; Hedberg, per. comm. 2010; Norrman, per. comm. 2010.) In line with this, the Swedish market for sold bread was diverse at the time of this study (cf., e.g., SIK, 2009).

Due to this, and since it early in the study of the bread test case was indicated that environmentally significant organisational practices were spanning the production of more than one bread type, the functional unit of comparison seemed to need to be of a general character. It was therefore chosen to be *one kg of soft bread consumed by the final customer*. This functional unit is based on the weight of the product is contrary to "nutritional and economic value" (Roy et al., 2009, p. 3). The choice of functional unit in this test case, lies in line with the functional units in bread LCAs with similar purposes to the test case (cf. Andersson and Ohlsson, 1999, p. 26; Braschkat et al., 2003, p. 12; Roy et al., 2009, p. 3; SIK, 2009, p. 1).

5.1.2. Data collection

The bread test case is based on one interview combined with a guided tour, two additional guided tours, web pages of the covered three bakeries, and literature. Initially, studies of literature on LCA of bread and of web sites for information about at the time of the study operating bakeries in the Gothenburg area and in Sweden in general, were performed. This guided the selection of

the three bakeries studied. The interview (which was combined with a guided tour) was conducted at the first visited of the studied bakeries. This interview was designed both for getting a different perspective of the bakery visited than the tour would provide and for furthering the understanding of the bakery sector more generally.

5.1.3. About the three sub-cases

The three bakeries that the bread test case was based on studies of were the Pågen bakery plant in Gothenburg, the Dahls bakery on Källhusgatan in Gothenburg, and the Ambrosia bakery in Malmö. Their properties are outlined in the following and summarised in Table 5.1, further on in sub-sub-chapter.

The Pågen bakery studied was at the time of the study a bakery plant with among other a large-scale and industrialised production of soft bread. The company also operated one similar-sized bakery plant in Malmö, Sweden. Their Gothenburg bakery's product focus was at the time of the study soft bread, and this was complemented by a smaller share of sweet baked goods. At this time the company distributed nationwide within Sweden, and, to a smaller degree, they also sold their products on foreign markets. The company's total share of the Swedish soft bread market was approximately 35% in 2010. (Hedberg, per. comm. 2010.) Its head office was co-located with the company's bakery plant in Malmö (Pågen, 2012a). Consumer packaging was applied to each sales unit produced at their Gothenburg plant prior to distribution (Hedberg, per. comm. 2010).

The Dahls bakery studied was at the time of the study a bakery with a medium-scale production of soft bread. This production was to a smaller degree of an industrialised type. In addition to producing soft bread, the bakery produced sweet baked goods to a considerable degree. The company also operated a slightly smaller-sized bakery in a nearby area of Gothenburg. (Adem, per. comm. 2010.) The company distributed their products locally and regionally, to around 100 different supermarkets and cafés. Their retailers were mainly located in the Gothenburg metropolitan area, within 20 km from the city centre, while some of them were located up to approximately 100 km from Gothenburg. (Dahls 2012a.) The company's head office was co-located with the studied bakery (Adem, per. comm. 2010; Dahls, 2012b). The focus of the bakery's soft bread products was to provide non-wrapped freshly baked bread (Adem, per. comm. 2010).

The Ambrosia bakery was at the time of the study a medium-sized to small-sized bakery with a very low degree of industrialisation of its soft bread production. The bakery was the company's only production facility, and produced mainly sweet bakery goods. The distribution was local, and their products were sold at six shops owned by the company and at three supermarkets. All nine of these were located in the city of Malmö. The company's head office was co-located with the bakery. Their soft bread focus was to provide non-wrapped freshly baked bread. (Norrman, per. comm. 2010.)

Table 5.1: Overview of general characteristics of the three bakeries

	Pågen	Dahls	Ambrosia
Site studied	Gothenburg bakery	Källhusgatan bakery, Gothenburg	Malmö bakery
Head office	At their Malmö bakery	At the studied bakery	At the studied bakery
Scale of soft bread production at the studied site	Large-scale	Medium-scale	Small-scale to medium-scale
Distribution	Nationwide and to a smaller degree to foreign markets	Locally and regionally	Locally

5.2. Life cycle assessments review

Through existing LCAs (Andersson and Ohlsson, 1999; Braschkat et al., 2003; Roy et al., 2009; SIK, 2009), guidance can be found on the product life cycle environmental performance of bread baked at Swedish bakeries from mainly four different perspectives. First, it is available regarding Swedish bread on average (Andersson and Ohlsson, 1999; SIK, 2009). Second, it is presented regarding bread produced at different scales (Andersson and Ohlsson, 1999; Braschkat et al., 2004; SIK, 2009). Third, it is present regarding different bread types produced in Sweden (SIK, 2009). Fourth, and finally, it exists for five different environmental impact categories for Sweden – global warming potential (GWP), energy use, acidification potential (AP), eutrophication potential (EP), and photo-oxidant formation potential (Andersson and Ohlsson, 1999; SIK, 2009).

Based on these studies, the product life cycles of Swedish soft bread from bakeries excluding the bread that goes through a final baking process at the retailer are reported to contribute to GWP by around 0.4–0.9 kg CO_2-equivalents per kg bread at the retailer, according to a publication from 2009 on an LCA (SIK, 2009). These bread product life cycles figures translate to a contribution to correspondingly between around 0.2% and 0.5% of the GWP from activities on Swedish territory in 2010 (FCCC, 2013, p. 14) per person living in Sweden (SCB, 2013), when based on bread consumption figures from 1998 (Nationalencyklopedin, 2001).

Regarding the other mentioned impact categories, the reported energy use for the product life cycles of the same types of bread spans from around 8 to 13 kWh per kg bread at the retailer (SIK, 2009). Reported bread product life cycle impacts for the three additionally mentioned types of impacts are available through a publication from 2009 on an LCA on the product life cycle of one kg of white bread produced in Sweden. The study was reported to have covered three different scales of bread production, spanning from a large industrial bakery that distributes its products

nationwide via a regionally distributing industrial bakery to a local bakery, and the product life cycles were covered until the use phase but excluding use phase losses. In this LCA publication, these bread product life cycles were reported to result in around 0.08–0.17 mol H+ of AP, around 90–160 g O_2 of EP, and around 1.0–1.8 g ethene equivalents of photo-oxidant formation potential. (Andersson and Ohlsson, 1999.)

Combining the standard LCA approach of dominance analysis with the three different scales of bread production covered in the 1999 LCA publication, some guiding figures can be obtained for the mentioned environmental impact categories. The processes of agriculture, transports, and food processing were for GWP together attributed the dominant share of it, while the other processes of packaging and the consumer phase together were not attributed more than around 10% of total product life cycle GWP. Of total product life cycle GWP, agriculture was reported to contribute to around 30% for the nationwide distributer, around 50% for the regional distributer, and around 60% for the local bakery. Further, transports were reported to contribute to total product life cycle GWP with around 40% for each of the nationwide and regional distributers and to less than 5% for the local bakery, and food processing to around 20% for the nationwide distributer, to around 10% for the regional distributor, and to around 30% for the local bakery. In total, the product life cycle of the nationwide distributer was reported to contribute to around 50% more GWP than each of the product life cycles of the two smaller scales of production. (Andersson and Ohlsson, 1999.)

Regarding energy use, of total energy use in these product life cycles, food processing was reported to contribute to around 20–30% in each life cycle, and agriculture to around 10 % for the nationwide distributer and to around 20–25% for each of the two smaller scales of production. Further, transports was reported to contribute to total product life cycle energy use with 20% for the nationwide distributer, 25% for the regional distributer, and to less than 5% for the local bakery. The corresponding figures for packaging's contribution to energy use are around 25% for the nationwide distributer, around 10% for the regional distributer, and around 15% for the local bakery, and for the use phase's contribution to energy use around 15–25% for each of the production scales. In total, the product life cycle of the nationwide distributer was reported to contribute to energy use with around 75–80% more than each of the product life cycles of the two smaller scales of production was reported to contribute. (Andersson and Ohlsson, 1999.)

Regarding the additional impacts categories, the reported shares of contributions between processes and for the three different scales of production are almost similar to the ones for GWP for AP and only differs by food processing contributing to smaller shares. For EP, agriculture was reported to correspond to more than 80% in each of the three product life cycles and the product life cycle of the nationwide distributer was reported to result in around 60% higher EP than the regionally distributor's and to around 30% higher EP than the local bakery's. Of total product chain photo-oxidant formation potential, food processing was reported to contribute to around

50–55% for each of the nationwide and regional distributors and to more than 80% for the local bakery, and transports to around 35–40% for each of the nationwide and regional distributors. In total, the product life cycles of the two largest sized bread productions were reported to contribute to around 60–70% more photo-oxidant formation potential than the product life cycle of the local bakery. (Andersson and Ohlsson, 1999)

Based on the previously in this sub-chapter referred to 1999 LCA publication and on the visits and interview of the bread test case, functions of seeming relevance in the product life cycles of the case's three bakeries' soft bread have been identified. These functions are included in the graphical presentation in Figure 5.1, further on in this sub-chapter.

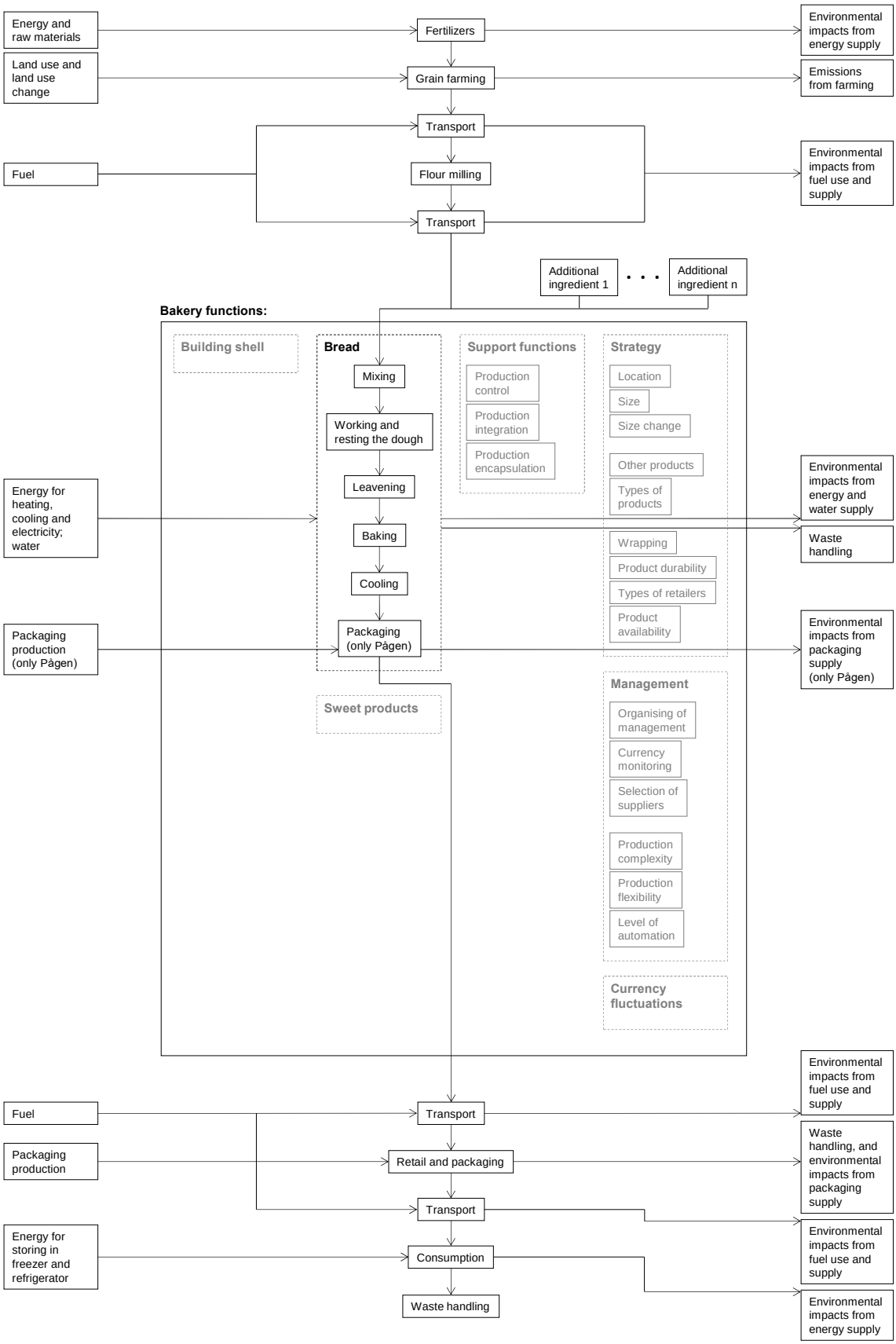


Figure 5.1: Overview of indicated product life cycle environmentally significant functions for the three bakeries' soft bread products. Directly through material and energy connections environmentally contributing functions in black, and indirectly contributing ones in grey.

5.3. Socio-material points of interaction at the product life cycles

The socio-material interactions at the product life cycles via which organisational practices have been indicated to cause considerable environmental consequences in the bread test case are connected to purchasing of supplies (A), production automation and product focus (B), production intervention approaches (C), and retailer aspects (D). The indicated environmental consequences of practices traced from these interactions at the studied bakeries' soft bread production are developed in the subsequent four sub-chapters.

5.4. Purchasing of supplies (A)

The supply of flour to Swedish bakeries is relevant to take a closer look at among other since it is both an environmentally impacting part of the bread product life cycle, and since it may come from so few sources that it can be possible to control it (cf. Hedberg, per. comm. 2010). The main identified environmental impacts from this supply come from transports and agriculture. Regarding these transports, larger scales of production can be assumed generally to require larger transport distances for this supply but may also facilitate more environmentally efficient transports per functional unit. (cf. Andersson and Ohlsson, 1999; Hedberg, per. comm. 2010.) Regarding this agriculture, grain production for flour production is generally considered to result in considerable environmental impacts (cf. Andersson and Ohlsson, 1999), and particularly fertilizer use has been pointed out (van Holderbeke et al., 2003, p. 18). Since flour generally is the main ingredient for bread production (cf. Andersson and Ohlsson, 1999; Adem, per. comm. 2010; Hedberg, per. comm. 2010; Norrman, per. comm. 2010), this ingredient might compared to other bread ingredient be particularly relevant to consider further. In addition, one type of flour may be the dominating source for a bakery (cf. Adem, per. comm. 2010, p. 3). Further, the bakeries covered in the bread test case produced, besides soft bread, sweet baked goods that were reported to or indicted to require many, and often exotic, ingredients, and sourcing these diverse and often in distant locations from Sweden produced ingredients seem to require different approaches (cf. Norrman, per. comm. 2010).

Regarding the three bakeries covered in the bread test case, the Pågen bakery can be characterised by a very large scale of production (Hedberg, per. comm. 2010) and by 90% of its products' volume consisting of soft bread mainly containing flour (Hedberg, per. comm. 2010, p. 10). Thus, large volumes of flour is used and it is a dominating ingredient. Therefore, the flour supply to the bakery is, if the company of Pågen decides to do so, likely both to be controlled regarding impacts from grain agriculture and to be performed using optimised flour chain transports. In line with these possibilities, the company has highlighted that they have believed that producing grain at a close distance from the bakery is environmentally advantageous and they present that this is achieved by owning a mill 40 km from their Malmö bakery (Pågen, 2012b).

However, their Gothenburg bakery's demand for flour is so large compared to that region's limited grain production (cf. Statens Jordbruksverk, 2015) that it is probably only possible and feasible to source the grain needed for this bakery from areas at considerably more remote locations than 40 km away.

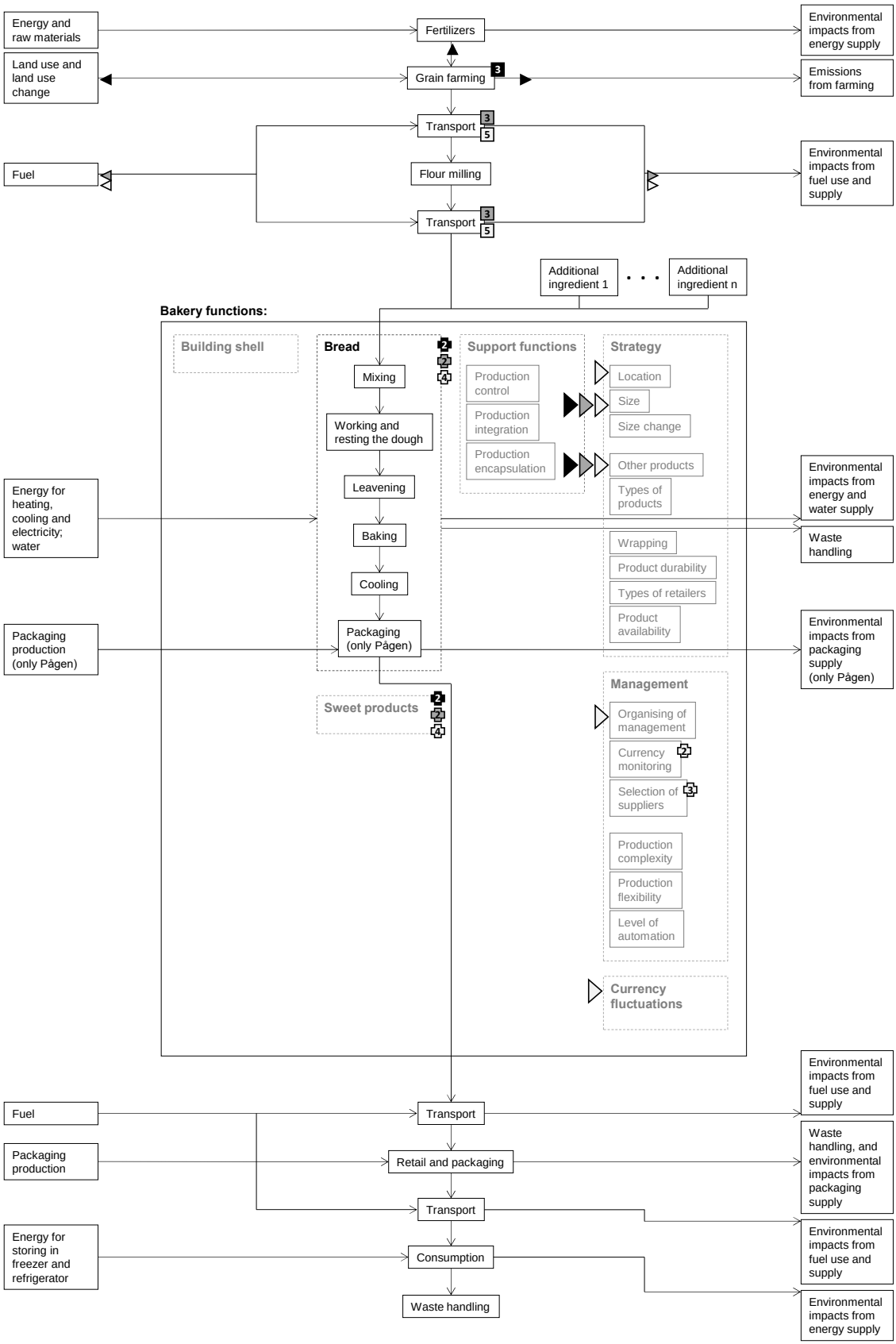
The Dahls bakery covered in the bread test case can be can be described as having had a moderately large size of production. In addition, the soft bread share of the bakery's products volume was large but not as large as at the Pågen bakery (Adem, per. comm. 2010; Hedberg, per. comm. 2010). The Dahls bakery mainly used one type of flour, which was supplied to a silo in the bakery, at a moderate frequency (up to several weeks between deliveries) (Adem, per. comm. 2010, p. 3). This bakery was located in Gothenburg, which, as already pointed out, is an area with limited grain production. Taking these conditions together, the Dahls bakery may have had a moderately large impact over the crop farming and its flour supply transports were likely optimised to a moderate degree, while the combined flour and grain transport distance might have been considerably longer than 40 km one-away.

The Ambrosia bakery covered in the bread test case ran a medium to small scale of business, and they focussed more on sweet baked goods than on bread. These sweet products used a wide range of ingredients that needed to be imported to Sweden, such as almonds and citrus fruits. Besides flour, they therefore also needed to purchase substantial amounts of a large number of ingredients. Because of these not easily discernible and many import conditions, the company was affected by fluctuations of currency rates. The company CEO meant that the company's size was too small for them to be able to well enough on their own keep track of these currency rate changes. Consequently, Ambrosia had recently before the time of this study switched from two local distributers to buying all its ingredients from a Scandinavia-wide purchasing organisation for bakeries – Din Bagare Skandinavien AB. (Norrman, per. comm. 2010.) Therefore, flour and grain supply transports were potentially longer and less easy to optimise. Further, due to the likely many intermediary steps in this flour and grain supply, the grain source might have been less possible to influence by the bakery.

See Table 5.2 and Figure 5.2, further on in this sub-chapter, for summaries of the described types of purchasing of supplies and their indicated environmental significance.

Table 5.2: Purchasing of supplies (A)

	Pågen	Dahls	Ambrosia
Potential control of farming's environmental impacts: generally indicated to be increased by larger scales of business, by focussing on soft bread, by using fewer types of flour, and by fewer intermediaries in the supply from grains	Very large scale of business, a large focus on soft bread, and a flourmill was owned by the company.	Intermediate scale of business, a moderate focus on soft bread, and flour use dominated by one type of flour.	Intermediate to small scale of business, little focus on soft bread, and an indication of many supply intermediaries.
Supply transports optimisation, which generally is indicated to be increased by larger scales of business, by focussing on soft bread, by using fewer types of flour, and by fewer intermediaries in the supply from grains	-||-	-||-	-||-
Supply transports distance, which generally is indicated to be increased by larger flour demand, by fewer flour types, by focussing on other products than soft bread, by limited nearby grain production, and particularly when nearby grain production is abundant by purchases via centralised organisations with a narrow focus	Very large flour demand, a large focus on soft bread, limited nearby grain production, and a flourmill was owned by the company.	Intermediate scale of business, flour use dominated by one type of flour, a moderate focus on soft bread, and limited nearby grain production.	Intermediate to small scale of business, little focus on soft bread, and a change from local suppliers to ingredients supply via a centralised Scandinavia-wide purchasing organisation targeting bakeries only.
➔ A more detailed study of the bakeries' control of and potential control of grain production and their impact on environmental performance, and the characteristics of flour and grain supply optimisation and distances may reveal environmental impacts differences between the product life cycles of the three studied bakeries.			



Indicated interaction chain based on functions and material and energy connections. Each marked function covers the indicated function or at least two of its sub-functions.
Numbers represent their step positions in the chain where needed for clarity.

▷ Furthest function involved in the furthest traced indicated interaction

✣ Indicated intermediate interaction step at the function

□ Interaction step that is indicated to cause environmental impacts via material and energy connections from the function

△ Main initial influence on material and energy connections from the interaction chain. Points in direction of successively influenced material and energy connections.

◆ Level of control of farming conditions

◈ Supply transports optimisation

◇ Supply transports distances

Figure 5.2: Main covered interaction paths connected to the purchasing of supplies that is indicated to influence product life cycle environmental performance

5.5. Production automation and product focus (B)

Regarding production automation and product focus, it was indicated in the bread test case that the levels of automation of the production procedures and product design were of environmental significance. The production automation level practices that were identified to be of potential environmental relevance were types of measuring, degrees to which the baking machinery was built-together, and contamination prevention. A higher degree of automation of measuring may increase the possibility to act quickly and accurately but the person receiving the information must be able to interpret it well and it may have a negative impact on production flexibility when for example unexpected equipment failures occur. Thus, automated measuring may either increase or decrease product quality and product quality variation and subsequently the satisfaction and associated level of discarding by consumers. The Pågen factory used, in addition to local measuring, control rooms not directly adjacent to the production equipment, and had the highest degree of automation of the three studied bakeries. The Dahls bakery instead used displays near the production for the control of, for example, baking oven temperature and moisture control. Direct estimation was the main type of measuring used at the Ambrosia bakery. (Adem, per. comm. 2010; Hedberg, per. comm. 2010; Norrman, per. comm. 2010.)

A built together production was indicated to have several potentially environmentally negative consequences. It was indicated to result in the need for staff to cover large areas, and this might decrease the possibility to exchange information about the state of the production between staff. The coverage of such large distance was only found at the Pågen facility out of the three bakeries. There, bakers were moving along large distances. (Adem, per. comm. 2010; Hedberg, per. comm. 2010; Norrman, per. comm. 2010.) In addition, a built together production makes it more difficult to continue the rest of the process if equipment failure occurs at one production step. The quality and discarding aspects that are potentially connected to the measuring automation degree, may also be influenced by these different effects of the level of built together production.

However, a high degree of automation makes it possible to protect against contamination in the bakery. This was the case on some production lines at the Pågen bakery (Hedberg, per. comm. 2010, p. 8), and for some production stages at the Dahls bakery (Adem, per. comm. 2010), but not at the Ambrosia bakery (Norrman, per. comm. 2010). In addition, the Pågen bakery used specific detection equipment to discover potential contamination in their products. It was argued that the use of this automation of production lines and this detection equipment made it possible to produce a bread that could be stored for a longer storage time before it became inedible. (Hedberg, per. comm. 2010.) Thereby, they may assist in lowering the need for customers to use

freezers or fridges for storage of the bread and in lowering the need of transportation if bread is bought less often by final consumers. On the other hand, the bread might more easily become discarded due to the difficulty of keeping track of its condition when it stays fresh during a longer time span than other bread.

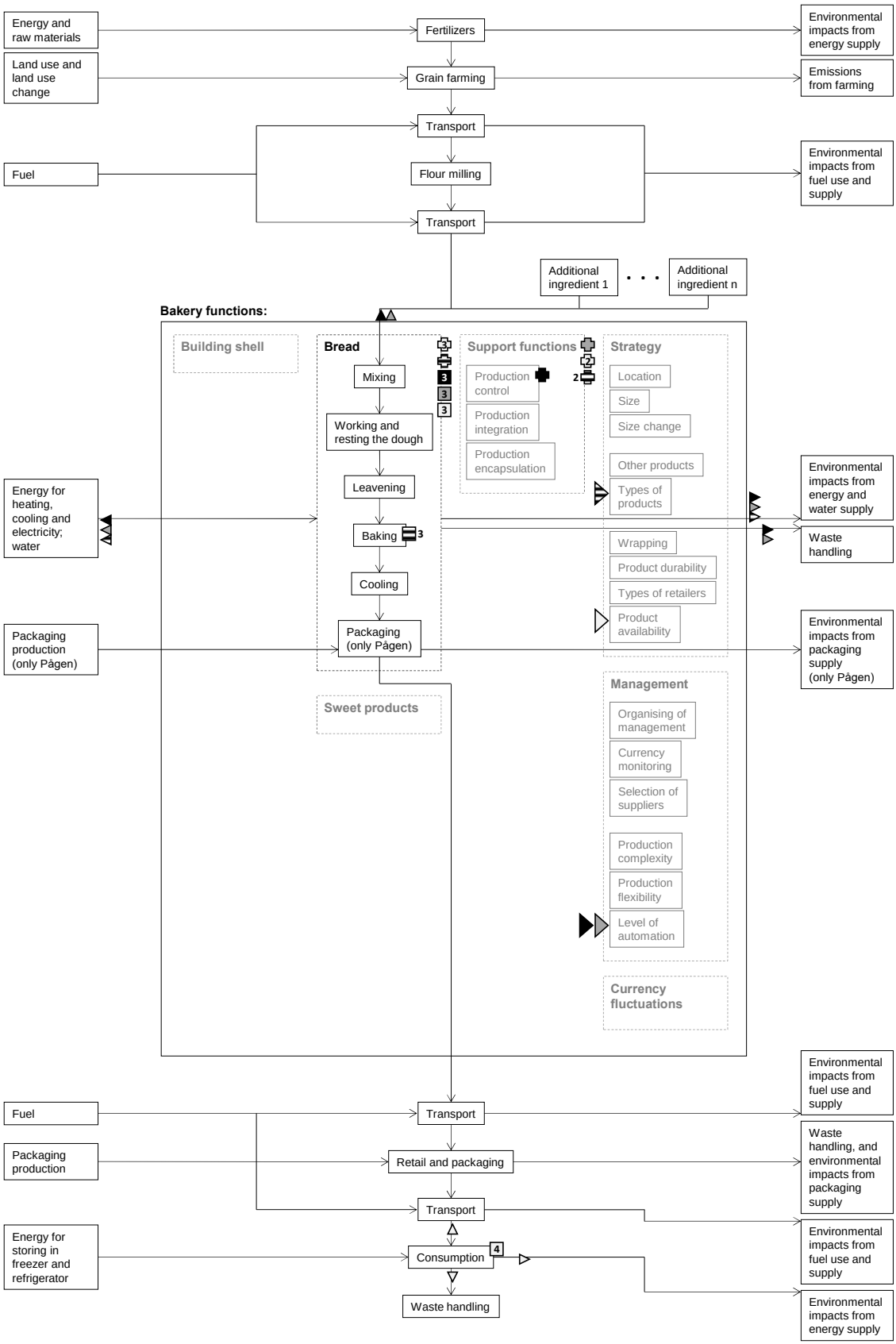
Regarding product design, thin soft bread was indicated to require less baking time than soft bread loaves (around 3 and 8 minutes, respectively) (Hedberg, per. comm. 2010). Whether this results in different environmental impacts per functional unit depends on the design of the ovens and the associated additional need to heat for example the air and walls of the baking ovens. Of the three bakeries here studied, the Pågen bakery were identified to be experts on thin soft bread production (Hedberg, per. comm. 2010), while the Dahls bakery was focussing on producing semi-thick soft bread (rolls) (Adem, per. comm. 2010) and the Ambrosia bakery was focussing on thick soft bread (loaves) (Norrman, per. comm. 2010).

See Table 5.3 and Figure 5.3, further on in this sub-chapter, for summaries of the described types of production automation and product focus and their indicated environmental significance.

Table 5.3: Production automation and product focus (B)

	Pågen	Dahls	Ambrosia
A higher degree of automation of measuring potentially influences environmental impacts from consumer discarding levels through bread quality impacts by the possibility of more accurate synchronisation, by maybe producing information that is less easy to well interpret and apply by bakery staff, and by allowing less production flexibility	Extensive use of measuring devices. Both remotely and locally located presentation of information from these devices.	Moderate use of automated measuring devices. Only locally located presentation of information from these devices.	Little use of automated measuring devices. Only locally located presentation of information from these devices.
Higher degrees of built together machinery was indicated to result in larger areas to cover for each baker and in less possibility to control if equipment failure occurs at one production step, and subsequently these may influence environmental performance via the same paths as for the level of measuring automation	Built together machinery. The bakers cover large areas. Direct and remote steering.	Partly built together machinery. The bakers cover small areas while being partly separated by the equipment. Their work is based on teamwork, work rotation, and a non-hierarchical working environment. Only direct steering.	Only to a low degree built together machinery. The bakers were not separated from each other. Only direct steering.
Contamination prevention was indicated to result in longer durability of the bread and subsequent environmental performance influences through by consumers use of less environmentally impacting storage, lower frequency of bread purchasing trips, and more discarding due to difficulties of adjusting to and discovering when the bread turns inedible	The bread is protected from bacteria etc. Automatic monitoring of contamination such as small stones.	Some protection of the bread from bacteria etc. during pre-baking. No monitoring of contamination such as small stones.	No protection of the bread from bacteria etc. No monitoring of contamination such as small stones.
Thin soft bread may require less energy for baking	Experts at producing thin soft bread.	Focus on medium thick soft bread (rolls).	Focus on thick soft bread (loaves).

➔ A more detailed study of consumers' levels of and reasons for soft bread discarding, of how different production practices influence bread quality, of trips for bread purchasing and bread storage, and of energy use for thin bread baking may reveal environmental impacts differences between the product life cycles of the three studied bakeries.



Indicated interaction chain based on functions and material and energy connections. Each marked function covers the indicated function or at least two of its sub-functions. Numbers represent their step positions in the chain where needed for clarity.

- Furthest function involved in the furthest traced indicated interaction
- Indicated intermediate interaction step at the function
- Interaction step that is indicated to cause environmental impacts via material and energy connections from the function
- Main initial influence on material and energy connections from the interaction chain. Points in direction of successively influenced material and energy connections.
- Degree of use of automated measurements
- Degree of built together machinery
- Degree of contamination prevention
- Degree of focus on thin soft bread

Figure 5.3: Main covered interaction paths connected to the production automation and product focus that is indicated to influence product life cycle environmental performance

5.6. Production intervention approaches (C)

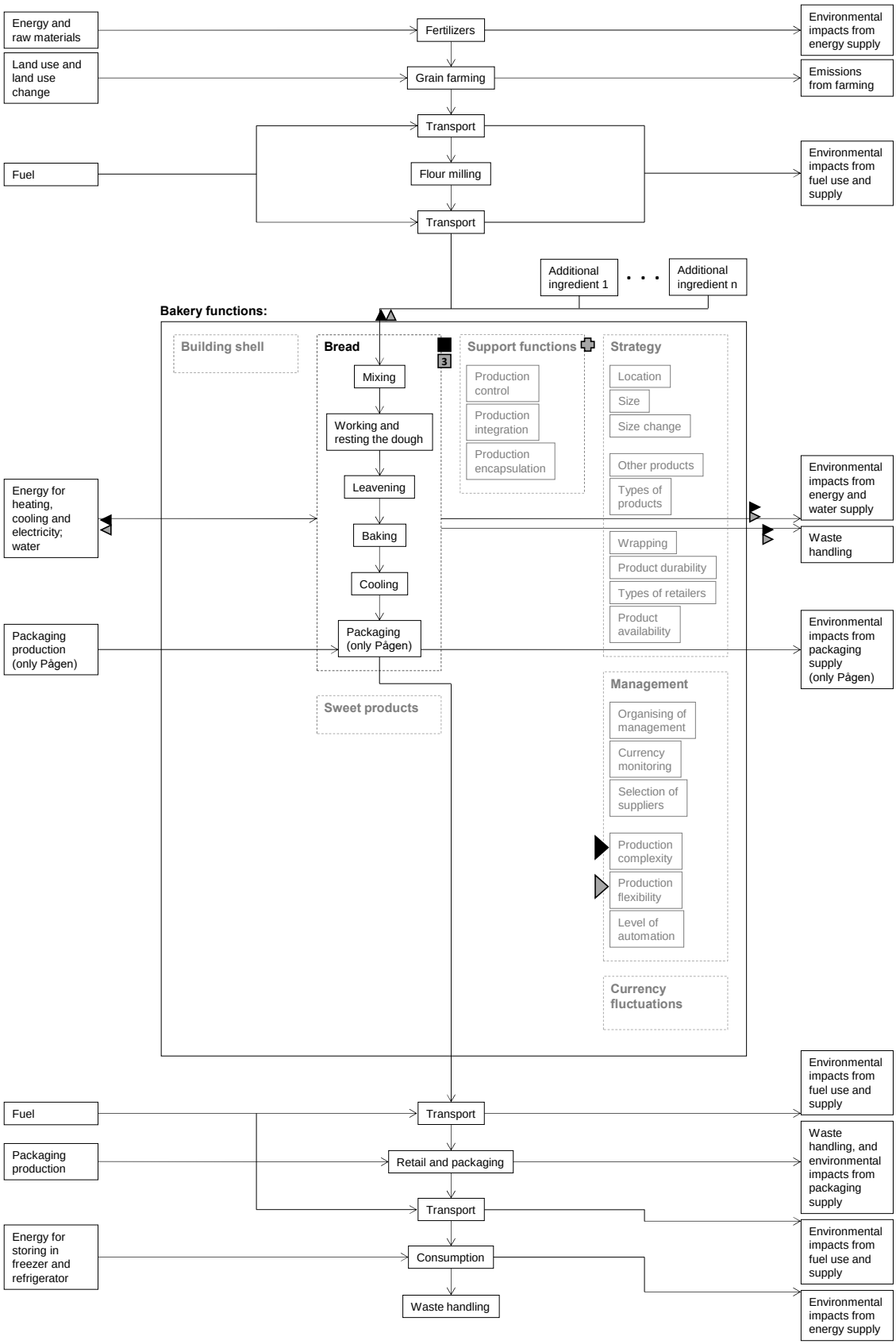
Regarding production intervention approaches, it was indicated in the bread test case that product and production complexity and production flexibility were of potential environmental significance. Regarding complexity, it was indicated that the production equipment at the Pågen bakery was highly specialised. It was stated that considerable training was needed for a baker to learn to master the handling of a production line where he or she had not worked earlier. (Hedberg, per. comm. 2010.) The Dahls bakery was found to use considerably less complex machinery (Adem, per. comm. 2010), and the Ambrosia bakery equipment was found to be even less complex. It was stated that the latter bakery on purpose used very basic production methods and recipes. It was stated that they thereby easily could let stand-ins continue the production without any particular difficulties when for example a baker could not work due to illness. (Norrman, per. comm. 2010.) These indicated differences in complexity practices between the three bakeries might lead to differences between the bakeries' product life cycles environmental impacts from consumer discarding due to the quality aspects described in the previous sub-chapter.

Regarding flexibility, we here present aspects of it that are not necessarily strongly dependent on the degree of production automation. The flexibility degree at the Pågen bakery was found to be low. For example, the ovens were indicated to be to a high degree closed systems, and individual bread pieces could in general not easily be checked in or removed from the production lines. (Hedberg, per. comm. 2010.) At the Dahls bakery, the ovens were less closed for interaction and could be checked manually to determine if the baking was proceeding successfully or not (Adem, per. comm. 2010). At Ambrosia, the degree of flexibility was indicated to be even higher since it was stated that also individual trays of products could be taken out of the oven while others were left for further baking (Norrman, per. comm. 2010, p. 13). These indicated differences in flexibility practices between the three bakeries might lead to differences between the bakeries' product life cycles environmental impacts from consumer discarding due to the quality aspects described in the previous sub-chapter.

See Table 5.4 and Figure 5.4, further on in this sub-chapter, for summaries of the described types of production intervention approaches and their indicated environmental significance.

Table 5.4: Production intervention approaches (C)

	Pågen	Dahls	Ambrosia
Higher production and product manoeuvring complexity may result in environmental impacts from increasing consumer discarding as a reaction to bread quality problems	Complex production lines that take long time to learn to handle for a baker.	Considerably less complex machinery than at the Pågen bakery.	Even less complex machinery. Products are on purpose basic in design in order to facilitate continued production using stand-ins when for example a baker cannot work due to illness.
Higher degrees of flexibility to manoeuver production equipment may, if the equipment is well handled, facilitate correction of machinery imperfectness and result in environmental impacts from decreasing consumer discarding as a reaction to higher and more reliable bread quality	Low degree of possibility to for example check or remove single bread pieces.	Medium to high degree of flexibility. For example, the baking ovens could be checked manually.	High degree of flexibility. For example, individual trays could be taken out of the baking oven.
➔ A more detailed study of consumers' levels of and reasons for soft bread discarding and of how different production practices influence bread quality may reveal environmental impacts differences between the product life cycles of the three studied bakeries.			



Indicated interaction chain based on functions and material and energy connections. Each marked function covers the indicated function or at least two of its sub-functions.
Numbers represent their step positions in the chain where needed for clarity.

Furthest function involved in the furthest traced indicated interaction

Indicated intermediate interaction step at the function

Interaction step that is indicated to cause environmental impacts via material and energy connections from the function

Main initial influence on material and energy connections from the interaction chain. Points in direction of successively influenced material and energy connections.

Degree of production and product complexity

Degree of flexibility to manoeuver production equipment

Figure 5.4: Main covered interaction paths connected to the production intervention approaches that are indicated to influence product life cycle environmental performance

5.7. Retailer aspects (D)

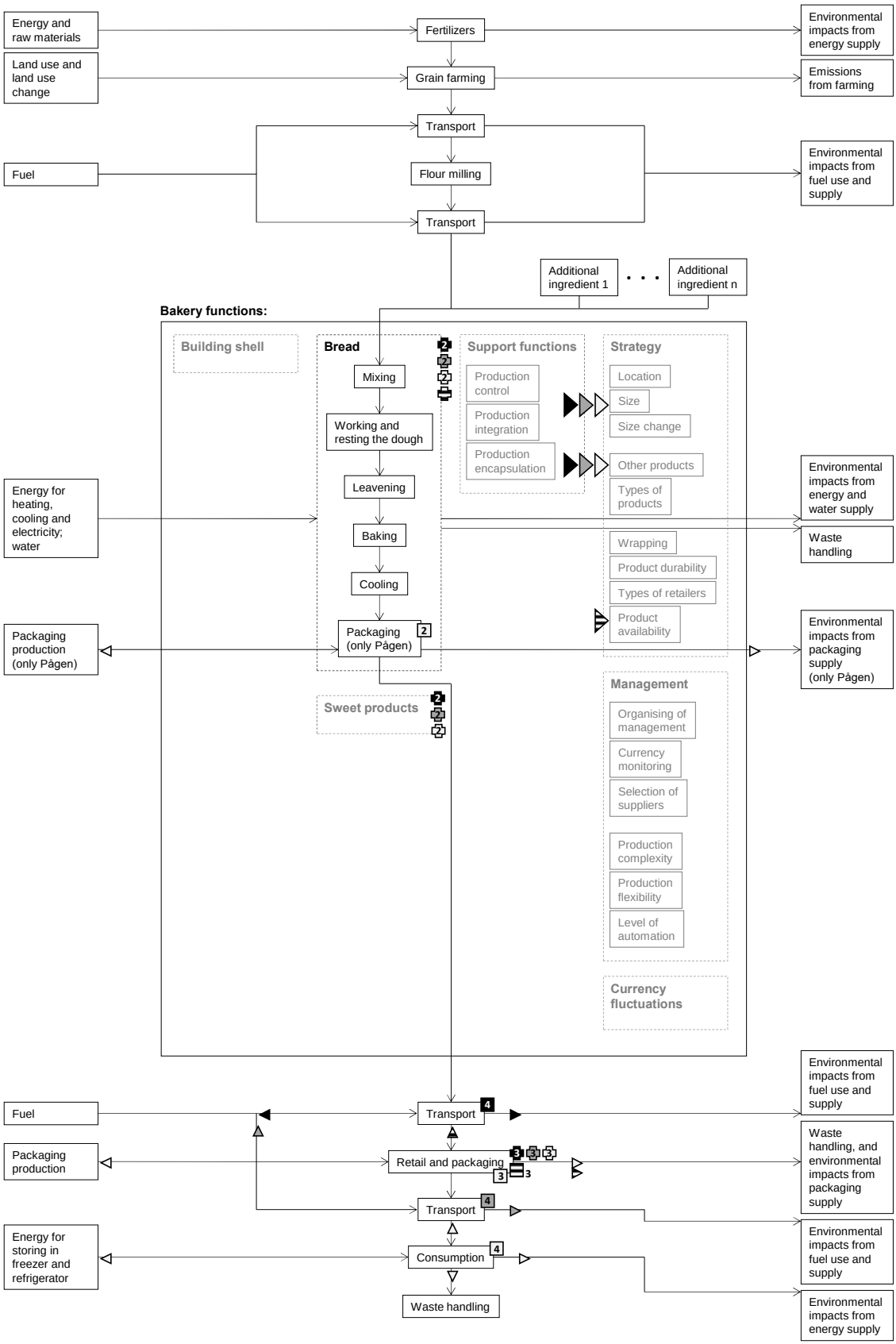
Regarding retailer aspects, this was in the bread test case indicated to be of environmental significance through distribution distance, type of retail, packaging, and overproduction. It was indicated that the distribution and packaging aspects were connected to the scale of business. It was indicated that the scale of business was closely connected to the distances of distribution to the three bakeries' retailers and to whether packaging was applied to each sales unit at the bakeries. In addition, it was indicated that the scale of business was partly through type of retailers connected to the transport needs of the final soft bread consumers. The supply ranges vary between the three studied bakeries. It spanned from the Pågen bakery's nationwide supply via the Dahls bakery's supply range of around 100 km to the Ambrosia bakery's citywide scale of sales. Regarding type of retailer, both the Pågen bakery and the Dahls bakery sold their products via supermarkets, while Ambrosia sold their bread via six of their own shops and via three supermarkets. Regarding packaging, the Pågen bakery applied plastic wrapping to each sales unit of their soft bread at the bakery, while the Dahls bakery covered in the test case did not use wrapping of single or multiple sales units at the bakery and while Ambrosia did not use wrapping at the bakery. However, the potential use of wrapping at the retailers and for storage through for example freezing by consumers ought to be included for an environmentally relevant comparison, but these were not studied in the screening here reported on. In addition, packaging may have environmental consequences on the storage and discarding aspects discussed in sub-chapter 5.5. (Adem, per. comm. 2010; Hedberg, per. comm. 2010; Norrman, per. comm. 2010.)

Regarding overproduction, this was identified to occur at the Pågen bakery and the Ambrosia bakery. The Pågen bakery deliberately aimed for an overproduction of 3%, in order for the retailers not to run out of their products at any time. These 3% were returned to the bakery, and made into and sold as pig fodder. (Hedberg, per. comm. 2010.) The Ambrosia bakery had problems with aligning production to demand levels, and considerable amounts of products were discarded by the retailers that were run by the bakery company. This was stated to the caused by a substantial expansion regarding the number of such hops (from one to six), and by customers demanding that the products were baked on the day of their purchase and that all types of products were available throughout the shops' opening hours. In addition, the monitoring of discarded amounts was made on an ad hoc basis and via the bakery company CEO. He was busy with and split between this task and many other tasks, regarded office work not to be important, and was located at up to ten km from each of the in turn not closely to each other located shops. (Norrman, per. comm. 2010.)

See Table 5.5 and Figure 5.5, further on in this sub-chapter, for summaries of the described types of retailer aspects and their indicated environmental significance.

Table 5.5: Retailer aspects (D)

	Pågen	Dahls	Ambrosia
Distance of distribution: nationwide supply is indicated to leads to considerable environmental impacts	Long distances to retailers (all of Sweden and beyond).	Retailers mainly in the Gothenburg metropolitan area.	Retailers within the city of Malmö.
Retailer types: larger supermarkets may result in longer but fewer consumer transports	The retailers belong to major supermarket chains.	The retailers belong to major supermarket chains.	Six smaller bakery owned shops and three supermarkets.
Wrapping: can be used at the bakery, at retail and for storage by consumers, and has considerable environmental impact in itself but may also influence environmental impacts due to influence on storage and discarding	Each sales unit of soft bread is separately wrapped in plastic at the bakery.	Not wrapped before retail.	Not wrapped before retail.
Overproduction, which results in environmental impacts from all functions earlier in the product life cycle and from its use and transports depending on how this and distribution transports are connected	Planned overproduction: 3%, planned take-back, which was used for producing pig feed.	-	Considerable amounts discarded at the retailers run by the bakery company, seemingly due to customer demands and lack of management resources for aligning production and demand levels.
➔ A more detailed study of the distribution to retailers, consumer transports, wrapping at bakeries, retailers and consumers, and overproduction and the transports used for it may reveal environmental impacts differences between the product life cycles of the three studied bakeries.			



Indicated interaction chain based on functions and material and energy connections. Each marked function covers the indicated function or at least two of its sub-functions.
Numbers represent their step positions in the chain where needed for clarity.

- Furthest function involved in the furthest traced indicated interaction
- Indicated intermediate interaction step at the function
- Interaction step that is indicated to cause environmental impacts via material and energy connections from the function
- Main initial influence on material and energy connections from the interaction chain. Points in direction of successively influenced material and energy connections.
- Distribution distance
- Types of retailers
- Wrapped of the soft bread
- Overproduction management

Figure 5.5: Main covered interaction paths connected to the retailer aspects that are indicated to influence product life cycle environmental performance

5.8. Analysis and summary of the test case

In this sub-chapter, we present a combination of the outcome of an analysis of and a summary of the previously in this chapter presented thirteen bread production practices and their indicated potentially significant influence on the product life cycle environmental impacts. These environmental impacts were indicated to be moderate from the perspective of environmentally harmful emission and resource use occurring in Sweden. The degree of certainty of environmental significance of these practices have been found to lie around moderate. This is based on that the bread test case included actual guided bakery tours and an interview with a bakery CEO and environmental performance information from publications on mainly quantitative LCA results, and that these tours, this interview and this environmental information covered many but particularly not several of the identified further effects of the different practices. Further, each of the thirteen practices seem to be connected to each of the other practices in not necessarily discernible ways, mainly moderately but also for a considerable share weakly and for a small share strongly, and the seemingly definitely dominant condition connecting them was found to be size of business. This is outlined for the respective connections in Table 5.6, further on in this sub-chapter. In addition, the practices were found to be dependent on the product life cycle characteristics short durability, and large environmental consequences from transports. Further, the practices seem to include coverage of twelve seemingly generic issues that might to be of environmental relevance for many other activities in society and the main findings for all of the thirteen practices identified seem to be covered by these issues. They are size of business, level of upstream control, share of products with input materials with considerably different characteristics than the product studied, supply differentiation, connection between location and size, outsourcing due to difficulties handling external developments, complexity and flexibility of production and products, quality and its reliability, retailer types, management during organisational growth, coordination frequency, and planned overproduction. The taken together seeming importance of each of these for understanding each of the thirteen practices is mainly none or low and to smaller degrees either moderate, high, or very high. This is outlined per issue and per practice in Table 5.7, further on in this sub-chapter.

Table 5.6: Indicated strengths of connections between the covered practices connected to bread produced at bakeries

Indicated environmentally significant practice A: Purchasing of supplies at bakeries B: Production automation and product focus C: Production intervention approaches D: Retailer aspects	Strength of connection between the practice and the other practices. 0 = no or very weak, 1 = weak, 2 = moderate, 3 = strong												
	A.1	A.2	A.3	B.1	B.2	B.3	B.4	C.1	C.2	D.1	D.2	D.3	D.4
A.1 Farming's environmental impacts control degree: Is indicated to be higher by larger size of business, soft bread focus, fewer flour types, and fewer intermediaries to grain supply		3	2	2	2	2	1	2	2	2	2	2	2
A.2 Supply transport optimisation degree: Is indicated to be influenced through size of business, soft bread focus, fewer flour types, and fewer intermediaries to grain supply			2	2	2	2	1	2	2	2	1	2	2
A.3 Supply transport distance: Is indicated to be increased by larger flour demand size, focus on other products than soft bread, limited nearby grain production, and purchase via a centralised organisation with a narrow focus when nearby grain production is abundant				2	2	2	1	2	2	2	1	1	2
B.1 Automation degree: Is indicated to be influenced via possibility for accurate synchronisation, production of information that is difficult for staff to well utilise, and lowered flexibility on consumer discarding due to quality issues					3	2	1	2	2	2	1	2	2
B.2 Built together machinery degree: Is indicated to be influenced via control when one production part fails on consumer discarding due to quality issues						3	1	2	2	2	1	2	2
B.3 Contamination prevention degree: Its indicated influence via durability on consumers' storage, purchasing frequency, and discarding due to difficulties of adjusting to and discovering when the bread turns inedible							1	2	2	2	1	2	2
B.4 Bread thickness and baking: Indicated potential lower energy use for thinner bread types								1	1	1	1	2	1
C.1 Manoeuvring complexity of production and products degrees: Are indicated to influence consumer discarding due to quality issues									2	2	1	2	2
C.2 Manoeuvring flexibility of production degree: Its indicated influence on consumer discarding due to preventing quality issues										2	1	2	2
D.1 Nationwide distribution or not: Distance indicated to result in considerable environmental impacts											2	2	2
D.2 Supermarkets as retailers or not: Indicated to result in longer but fewer consumer trips												2	3
D.3 Wrapping at bakeries, retailers, and consumers types and amounts: Its indicated environmental impacts													2
D.4 Overproduction through planning or non-deliberately degrees: Indicated environmental impacts via them, their use, and how their transports and other transports are connected													

Table 5.7: Seeming generic issues and their indicated importance for explaining the covered practices connected to bread produced at bakeries

Seeming generic issues	Indicated importance for explaining the practices. 0 = no or low, 1 = moderate, 2 = high, 3 = very high												
	A.1	A.2	A.3	B.1	B.2	B.3	B.4	C.1	C.2	D.1	D.2	D.3	D.4
Size of business	3	3	3	2	2	3	1	2	2	3	2	3	3
Level of control of upstream activities	3	2	1	0	0	0	0	0	0	0	0	0	0
Share of products with input materials with considerably different characteristics than the product studied	2	2	3	0	0	0	0	0	0	1	1	1	1
Supply differentiation	1	1	1	0	0	0	0	0	0	0	0	0	0
Connection between location and size	1	0	3	0	0	0	0	0	0	0	0	0	0
Complexity and flexibility of production and products	0	0	0	3	3	2	0	3	3	0	0	0	0
Outsourcing due to difficulties handling external developments	1	1	3	0	0	0	0	0	0	0	0	0	0
Quality and its reliability	0	0	0	3	3	3	0	3	3	0	0	0	0
Retailer types	0	0	0	0	0	0	0	0	0	1	3	3	1
Management during organisational growth	1	2	3	0	0	0	0	0	0	0	1	0	3
Coordination frequency	0	0	1	0	0	0	0	0	0	0	0	0	3
Planned overproduction	0	0	0	0	0	0	0	0	0	2	2	0	3

Further, it seems for a considerable degree of the practices not clear whether they in a certain state would lead to increased, decreased, or similar product life cycle environmental impacts. Therefore, it seems not possible, based only on the bread test case, to make a ranking of environmental performance per functional unit between each of the three compared bakeries and their soft bread product life cycles – a more detailed study is necessary for that.

Nevertheless, the presentation based on the screening seems to show that the environmental performance is not easily deduced from the environmental impacts from bread ingredients, baking processes, and transportation distances, as would be the procedure in standard LCA. Even if no direct quantitative environmental differences were possible and feasible to present, the screening has *at least* shown that the studied bakeries operated with different business approaches and that the environmental performances seemed to depend on an intricate interplay of organisational practices with technology and material and energy. This includes, among other:

- Supply transport distance and its environmental impact through emissions from the fuel use of the transports

- Bread thickness and baking, and an indicated potential lower energy use for thinner bread types

- Overproduction and indicated environmental impacts via among other the need of additional inputs to production of bread discarded due to overproduction

Further, these and other of the identified practices seem to a large degree to have been considerably dependent on each other. A thorough nodal LCA organisation study might result in an understanding of how some of these and other practices are related and their magnitudes of influence on environmental performance. A reason why it may not be the result is the seeming intricate relations between the practices for a large share of them. Based on the list just prior to this paragraph, for example, supply transport distances, thicknesses of the bread produced and overproduction management were all together with other practices seemingly considerably were related to the size of business of the bakeries. These causes and effects likely to a moderate degree were difficult to discern due to many intricately involved causes, additional impacts on environmental performance of these, and that case studies probably only could cover certain specific modes of these practices. On the other hand, such a result seems in itself to be moderately relevant for pointing to the usefulness of searching for complementing approaches to direct changes to the organising for considerably lowering the environmental impacts caused by environmentally ineffective organising. Finally, the ratio between the occurrence of results useful for concrete actions and this pointing towards complementing approaches seems for bread product life cycle environmental performances with bakeries in Sweden as nodes to be moderately difficult to predict and the taken together gain of these results have been indicated to be moderate compared to using a screening approach. The components and overall findings on this reasoning on choosing between a screening and a thorough nodal LCA organisation study for this product type and this type of nodes is presented in Table 5.8, further on in this sub-chapter.

Table 5.8: Overview of findings from reasoning on differences in usefulness between a screening and a thorough nodal LCA organisation study for bread product life cycle environmental performances with bakeries in Sweden as nodes

Useful findings from the screening nodal LCA organisation study – summary		Operating business approach differences seem to have influenced environmental performance Identified intricate interplay between organising, technology, and materials and energy processes
Seeming gain of performing instead of screening a thorough nodal LCA organisation study	Environmental performance: Overall	Small
	Environmental performance: Per part of the system	Moderate to large
	Environmental performance: Over time	Moderate
	Organisational study	Moderate to large
	Producing a basis for carrying out concrete actions	Moderate
	Taken together: Magnitude of gain and its predictability based on the screening	Moderate gain Moderate predictability
	Taken together: Types of gain and their predictability based on the screening	Moderately producing a basis for carrying out concrete actions Moderately pointing to a need for complementing alternative approaches Moderate predictability

Further, it may also be worth to compare the results from and the outcome of the analysis of the bread test case with that bread belongs to a type of products that recently mainly have been highlighted due to a level of discarded products that has been presented as alarming: food (e.g., FAO, 2011). Bread discarding practices have been indicated to be of environmental significance in this chapter, but also to be considerably connected to other environmentally impacting practices in not easily discernible and many ways. Thus, it is indicated that manifold and not necessarily discernible relationships of management and environmental impacts from technology and

material and energy systems can be important to understand in what is discussed as a one-question issue.

6. BUS TRAVEL ON INTERCITY ROUTES (BASED ON TEST CASE 3)

In this chapter, we focus on the in the here reported on project identified organisational practices of indicated product life cycle environmental significance for the service bus travel on intercity routes and traced from the nodal site of a bus operation route. Intercity bus travel is a common mode of transportation in Europe (e.g., Eurolines, 2015; Swebus, n.d.), and bus travel is reported to cause, as transports by road in general (Fuglestvedt et al., 2008), considerable environmental impacts (Naturvårdsverket, 2015). Intercity bus travel is a particularly popular choice for medium range travel on distances were train connections are poor.

6.1. Study objects

6.1.1. Selection of study objects

Travel between Gothenburg, Sweden, and Oslo was in the bus travel test case studied for the three companies that operated bus services between these two cities at the time of the study (September 2010). For travel between these two cities, it was at that time also possible to take the train, to fly or drive a car, but for many, the bus was their first choice owing to low prices and the large number of departures per day. The distance between the cities is around 300 km, and train services were at the time of the study not prominent on this route.

6.1.2. Data collection

Empirical material used in the bus travel test case consists of observation at bus terminals and through travelling, brochures at sales points and internet documents. This material was collected for each of the three studied bus operators. The fieldwork was carried out intermittently between February 2009 and September 2010.

6.1.3. About the three bus operators

The three bus travel operating companies covered in the bus travel test case were Swebus Express, GoByBus and Bus4You. The services provided on the studied route by the three companies were very similar in several aspects. The services operated on the same roads between the two cities, and their timetables had identical departure times and their stops were located next to each other at the Gothenburg bus station. Since the services provided were almost identical, it was considered suitable to compare them using the screening approach of the test case to environmental performance of their respective organisational practices. The three companies are described in the

following, and an overview of the details that this description is based on is presented in Table 6.1, further on in sub-sub-chapter.

Swebus Express was at the time of the bus travel test case a large operator of scheduled public road transport services. They claimed to be the leading express bus company in Sweden with 10,000 departures per week and over 2 million passengers per year. Their bus services were since 2009 eco-labelled with 'Bra Miljöval' (Environmentally Benign Choice), issued by the Swedish Society for Nature Conservation. They did publish an environmental report and their environmental work on the internet. The company was by the time of the study owned by Nobina, previously known as Concordia. In total, Swebus Express, at the time of the study, operated 30 long-distance lines, reaching more than 150 destinations. Their destinations were mainly in Sweden, but cities located close to Sweden such as Oslo and Copenhagen were also included in their network. The Gothenburg–Oslo line was labelled as route number 820. It was also extended southwards, connecting to Copenhagen and further down the European continent.

GoByBus was at the time of the bus travel test case a smaller bus operator. At the time of the study, the company's recent organisational history contained several events. Until 2006, the company was known as Säfflebussen and run by an entrepreneur from Säffle, Sweden. In 2006, Säfflebussen was acquired by Nettbuss, a Norwegian bus company mainly operating local and regional lines in Norway. In 2008, Säfflebussen merged with the small, new bus operator Bus4You and Säfflebussen changed its name into GoByBus.

GoByBus and Bus4You were at the time of the study of the bus travel test case more or less run as two separate companies, but they shared garage and head offices in Borås, Sweden, 50 km east of Gothenburg. While GoByBus claimed to provide the cheapest trips, Bus4You sold "luxurious and comfortable" trips with three leather seats (two plus one seats) per row, wireless internet on board and electricity sockets by each seat. GoByBus and Bus4You each operated only two routes, their Gothenburg–Oslo route being one of them.

Table 6.1: Overview of general characteristics of three bus services from Gothenburg to Oslo (as of September 2010)

	Swebus Express	GoByBus	Bus4You
Travel service	Up to 10 departures/day	5 departures/day	2 departures/day
	Many trips were non-stop, with a travel time of 3:35, while others included stops along the route that extended the travel time to a maximum of 3:50	Travel times between 3:48 and 3:50	Travel time 3:35
	177 SEK was the price for a one-way trip on a weekday	216 SEK was the price for a one-way trip on a weekday (adults; students and particularly senior citizens paid considerable less)	243–290 SEK was the price for a one-way trip on a weekday (adults; students and senior citizens paid less)
General management	Marketed itself as the company with flexible travelling to many destination (had free wireless internet and electricity sockets by each seat, but it was not a prominent marketing point)	Marketed itself as the friendly and super cheap company: "only bicycling is cheaper" (had free wireless internet on some of their buses, but this was not a marketing point)	Marketed itself as "affordable luxury" and "faster than the train, more comfortable than flying" with only 2 + 1 seats/row, free wireless internet and electrical sockets by each seat
	Had a large website with pages describing fleet management, environmental strategy, research on public transportation, etc.	Limited amount of company information on company; their website was mainly dedicated to sales of bus travels	Limited amount of company information on company; their website was mainly dedicated to sales of bus travels

6.2. Life cycle assessment screening

The environmental comparison of the competing bus services was in the bus travel test case carried out using approximately the functional unit *environmental impact per one person-km*.

In order to understand the environmental impact generated in connection to three companies' operation on the route Gothenburg–Oslo, respectively, it was necessary to look into the organisation enabling the physical transport. This covered the bus trips between Gothenburg and Oslo, tickets handling, fuelling, garage services, and offices. Details about the environmental impacts are described for the different identified organisational practices of indicated environmental significance outlined in the remainder of this chapter. An overview of these

environmental impacts from an LCA perspective, and particularly of the bus operations functions related to them, is presented in Figure 6.1, further on in this sub-chapter.

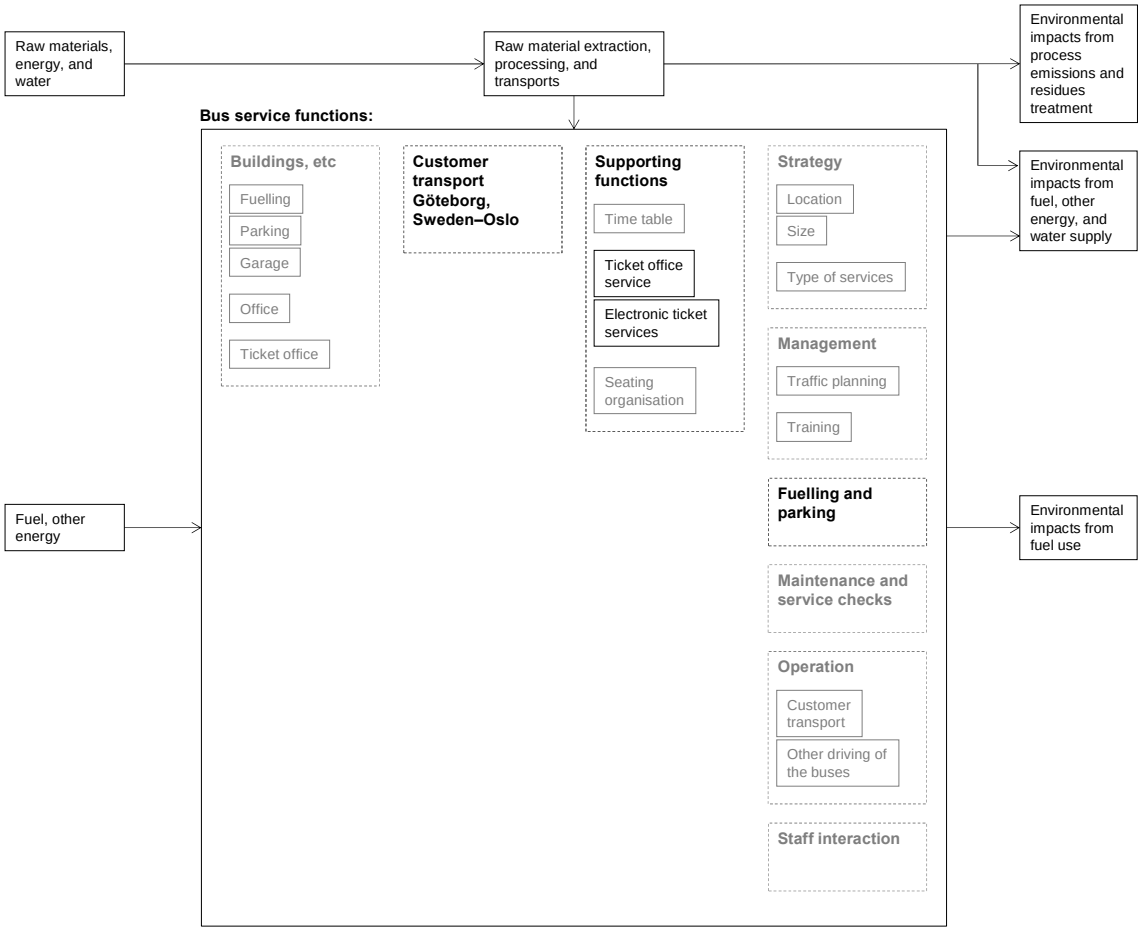


Figure 6.1: Overview of screened indicated product life cycle environmentally significant functions for the three bus services. Directly through material and energy connections environmentally contributing functions in black, and indirectly contributing ones in grey.

6.3. Socio-material points of interaction at the product life cycles

The socio-material interactions at the product life cycles via which organisational practices have been indicated to cause considerable environmental consequences in the bus travel test case are connected to driving style (A), ticket sales (B), fuelling, cleaning, servicing, maintenance and repairs at the garage (C), and fleet management (D). The indicated environmental consequences of practices traced from these interactions at the studied bus services are developed in the subsequent four sub-chapters.

6.4. Driving style (A)

Buses have different gearboxes than cars. There are, for example, gearboxes with 12 gears, as well as automatic ones. In addition, there is more than one way to brake. This means that drivers develop personal driving styles, with great differences in fuel efficiency. Different driving styles could theoretically lead to ± 15% differences in CO_2 emissions. The three in the bus travel test case covered companies were indicated to differ regarding driving style, as presented in Table 6.2, further on in sub-chapter. See Figure 6.2, further on in this sub-chapter, for an overview of these driving style practices and their indicated environmental significance.

Table 6.2: Driving style and its organisation (A)

	Swebus Express	GoByBus	Bus4You
General driving style	Most drivers had calm and smooth driving styles. Only occasionally, one ended up with a brusque driver. Buses were usually on time.	Most drivers had calm and smooth driving styles.	Most drivers had calm and smooth driving styles.
Eco-driving	Drivers got training in 'eco-driving'; eco-driving skills were often discussed by drivers.	No info on eco-driving.	No info on eco-driving.
➔ A more detailed study of driving styles in practice and driver's training may reveal environmental impacts differences between the three studied bus services.			

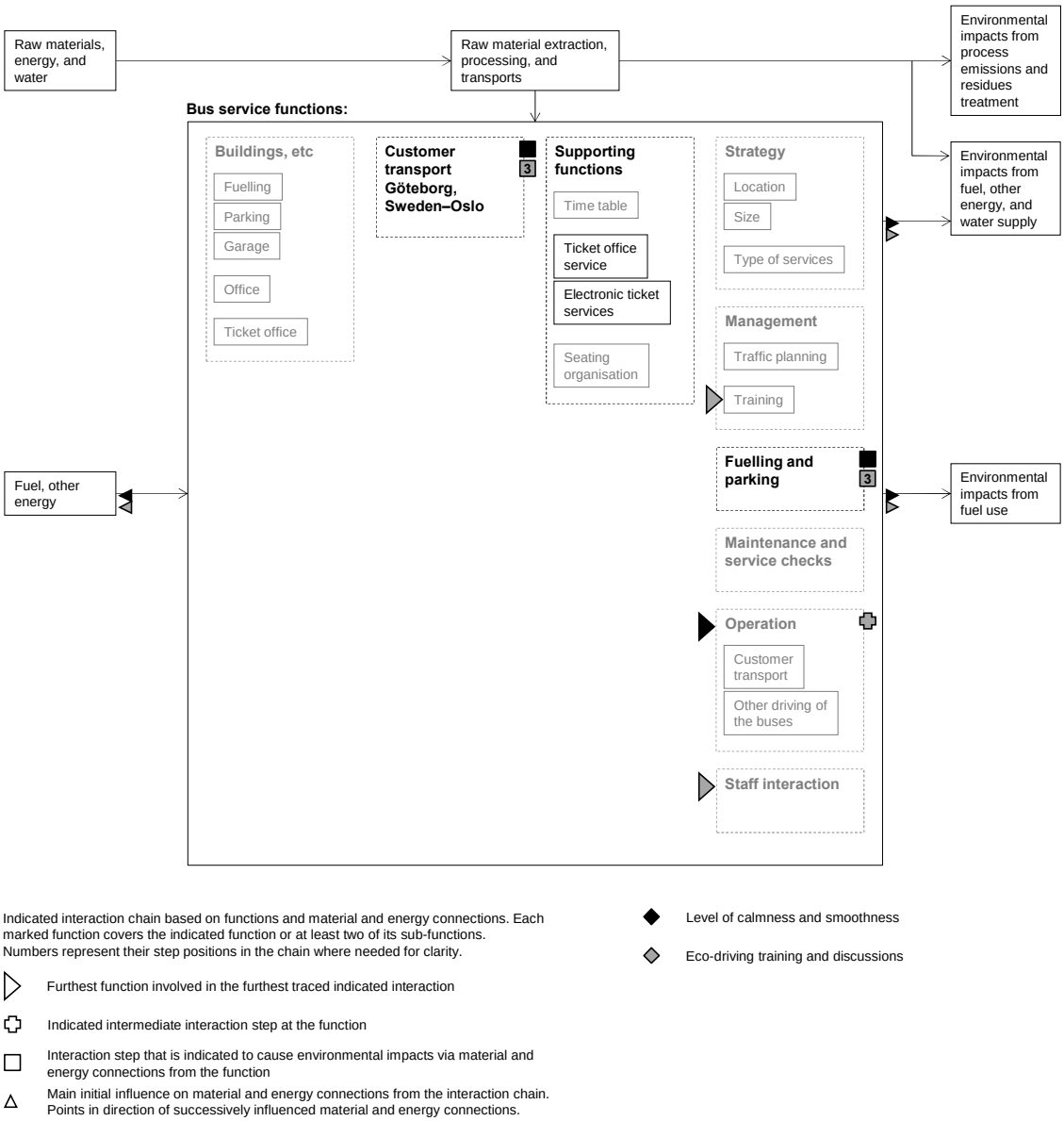


Figure 6.2: Main covered interaction paths connected to the driving style and its organisation that is indicated to influence product life cycle environmental performance

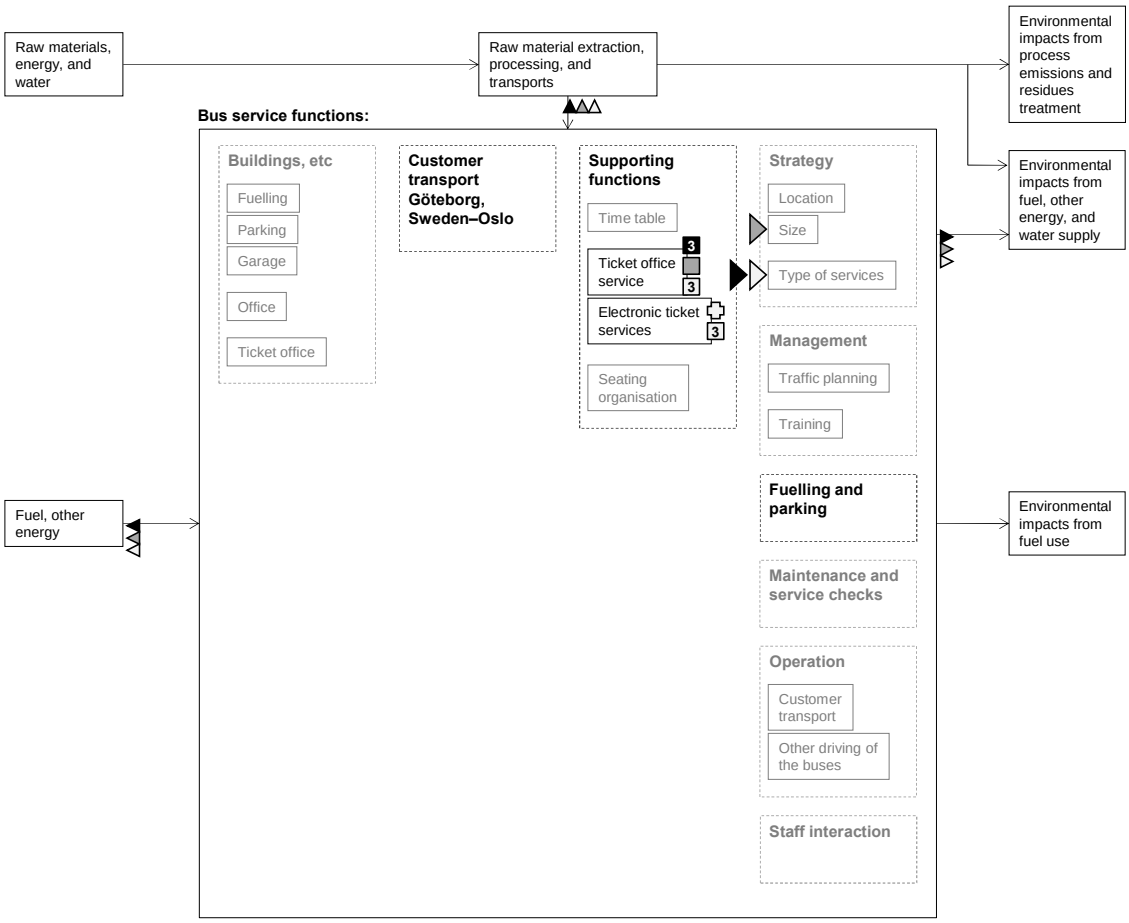
6.5. Ticket sales (B)

In the bus travel test case, it was found that tickets were mainly sold via the bus companies' web sites at the time of the study, but also over the phone, via applications on mobile phones and over the counter at the bus terminal. Ticketing used to be paper-based, but this changed rapidly into a range of options recently before this test case was studied. By the time of the study, it ranged from emailed tickets with a bar code to a code as an SMS to be shown to the driver when boarding. The environmental impact related to these ticket sales depend on the digital solution and to the space for ticket sales in bus terminals. The characteristics of ticket sales and its organisation is outlined for the three operators in Table 6.3, further on in this sub-chapter. See Figure 6.3, further

on in this sub-chapter, for an overview of these ticket practices and their indicated environmental significance.

Table 6.3: Ticket sales and its organisation (B). The rows in italics represent possibly to these connected but not in the bus travel test case further studied practices.

	Swebus Express	GoByBus	Bus4You
Sales office sizes	Small sales office with two to three counters in the bus terminal.	Bigger sales office with one counter in the bus terminal.	Shared sales office with GoByBus.
Number of routes served by the ticket offices	Served customers for all their other routes as well.	Served customers for two routes.	Sales procedures similar to GoByBus.
Other sales office presentation characteristics	*Stall with timetables, offers, etc. Often people were queuing.*	*Big posters, many brochures, abundancy of lights. One armchair for waiting customers, no queuing system.*	*Sales procedures similar to GoByBus.*
Use of electronic tickets and digital solution for this	Paper tickets over the counter; booking code over the internet.	Paper tickets over the counter or via email (no booking code).	Sales procedures similar to GoByBus.
Customer profiles	-	*Customers could register on the internet to view their bookings, travelling history, receive offers, etc.*	-
Seat reservation	-	-	*For an extra fee, customer could book their seat.*
➔ A more detailed study of the internet ticket services and the environmental impacts of the ticket offices may reveal environmental impacts differences between the three studied bus services.			



Indicated interaction chain based on functions and material and energy connections. Each marked function covers the indicated function or at least two of its sub-functions.
Numbers represent their step positions in the chain where needed for clarity.

- Furthest function involved in the furthest traced indicated interaction
- Indicated intermediate interaction step at the function
- Interaction step that is indicated to cause environmental impacts via material and energy connections from the function
- Main initial influence on material and energy connections from the interaction chain. Points in direction of successively influenced material and energy connections.

- Size of ticket sales office
- Number of routes served by ticket sales office
- Types of digital solutions used for electronic tickets

Figure 6.3: Main covered interaction paths connected to the ticket sales and its organisation that is indicated to influence product life cycle environmental performance

6.6. Garage practices (C)

The buses covered in the bus travel test case were fuelled and cleaned at the respective bus garages. In addition, service checks, maintenance and repairs were performed at these locations.

The locations of these garages determines whether fuelling and cleaning of the buses result in extra transport kilometres of the buses, and these locations differed between some of the studied operators, as outlined in Table 6.4, further on in this sub-chapter. See Figure 6.4, further on in this sub-chapter, for an overview of these garage location practices and their indicated environmental significance.

Table 6.4: Fuelling, cleaning, servicing, maintenance, and repairs of the buses, and their organisation (C)

	Swebus Express	GoByBus	Bus4You
Garage location	These operations were performed at garages in close proximity to bus terminal.	These operations were performed at a garage near Borås.	These operations were performed at a garage near Borås.
➔ Swebus Express had the environmental advantage of bus garages close to the bus terminal, while the garage used by GoByBus and Bus4You buses was located some 50 km away.			

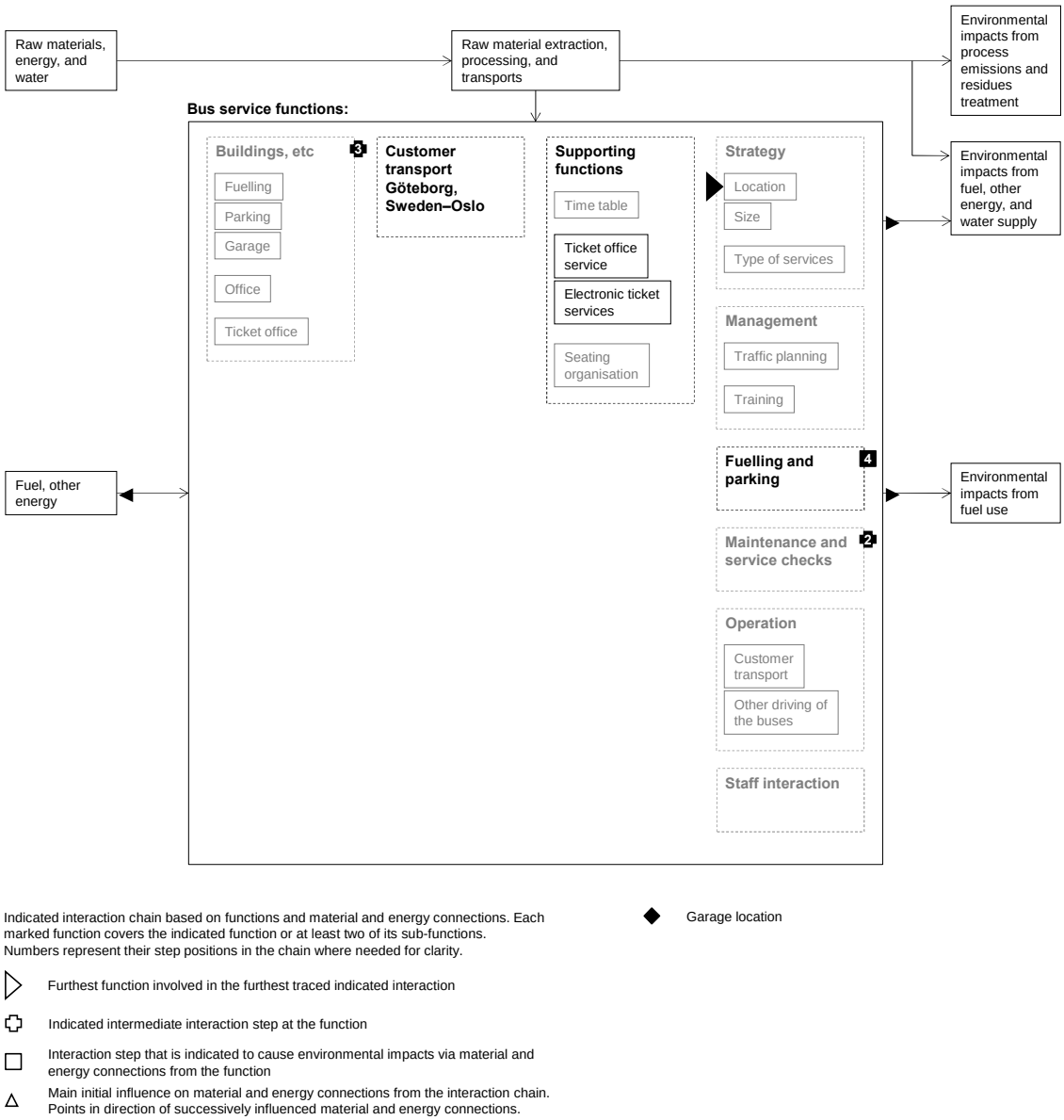


Figure 6.4: Main covered interaction paths connected to the fuelling, cleaning, servicing, maintenance and repairs of buses and its organisation that is indicated to influence product life cycle environmental performance

6.7. Fleet management (D)

Owing to relatively small production series, the interior of buses can be more or less hand-built and tailored to the needs of the clients. This allows each bus operator great freedom when ordering new buses. This can lead to different number of seats per bus, which in turn affect passenger eco-efficiency. In addition, age of bus, engine type and frequency of servicing influence fuel efficiency. In short, bus fleet management is crucial to the eco-efficiency of the bus journey. The details regarding these aspects found through the three sub-cases in the bus travel test case are outlined in Table 6.5, further on in this sub-chapter. An overview of the life cycle environmental

impact paths based on these practices differences is presented in Figure 6.5, further on in this sub-chapter.

Table 6.5: Bus fleet management and its organisation (D). The rows in italics represent possibly to these connected but not in the bus travel test case further studied practices.

	Swebus Express	GoByBus	Bus4You
Seats organisation on the buses	Ordinary two plus two seats/row; velvety upholstered seat.	Ordinary two plus two seats/row; velvety upholstered seat.	Special feature: leather seats, only three (two plus one) seats/row.
Fleet age	Varying age of buses, but older buses were replaced on a regular basis.	New buses.	Only brand new buses.
Bus leasing	*Ca 50% were on lease; 50% were owned.*	*No information on ownership of fleet.*	*No information on ownership of fleet.*
Servicing	*No information on frequency of servicing.*	*No information on frequency of servicing.*	*No information on frequency of servicing.*
Scheduling	Scheduling was said to consider rush hours to avoid unpredictable travel time and to reduce emissions.	No information on scheduling, but had adopted more or less a timetable that was identical to the one of Swebus Express.	No information about scheduling.
➔ Bus4You had an environmental disadvantage relative the other two companies owing to lower passenger efficiency. GoByBus and Bus4You had the environmental advantages of new buses, whereas the Swebus Express bus fleet was of a more varied age. A further study of the distribution of engine types (Euro 1–5) and use of alternative fuels may reveal additional environmental impacts differences between the three studied bus services connected to fleet management.			

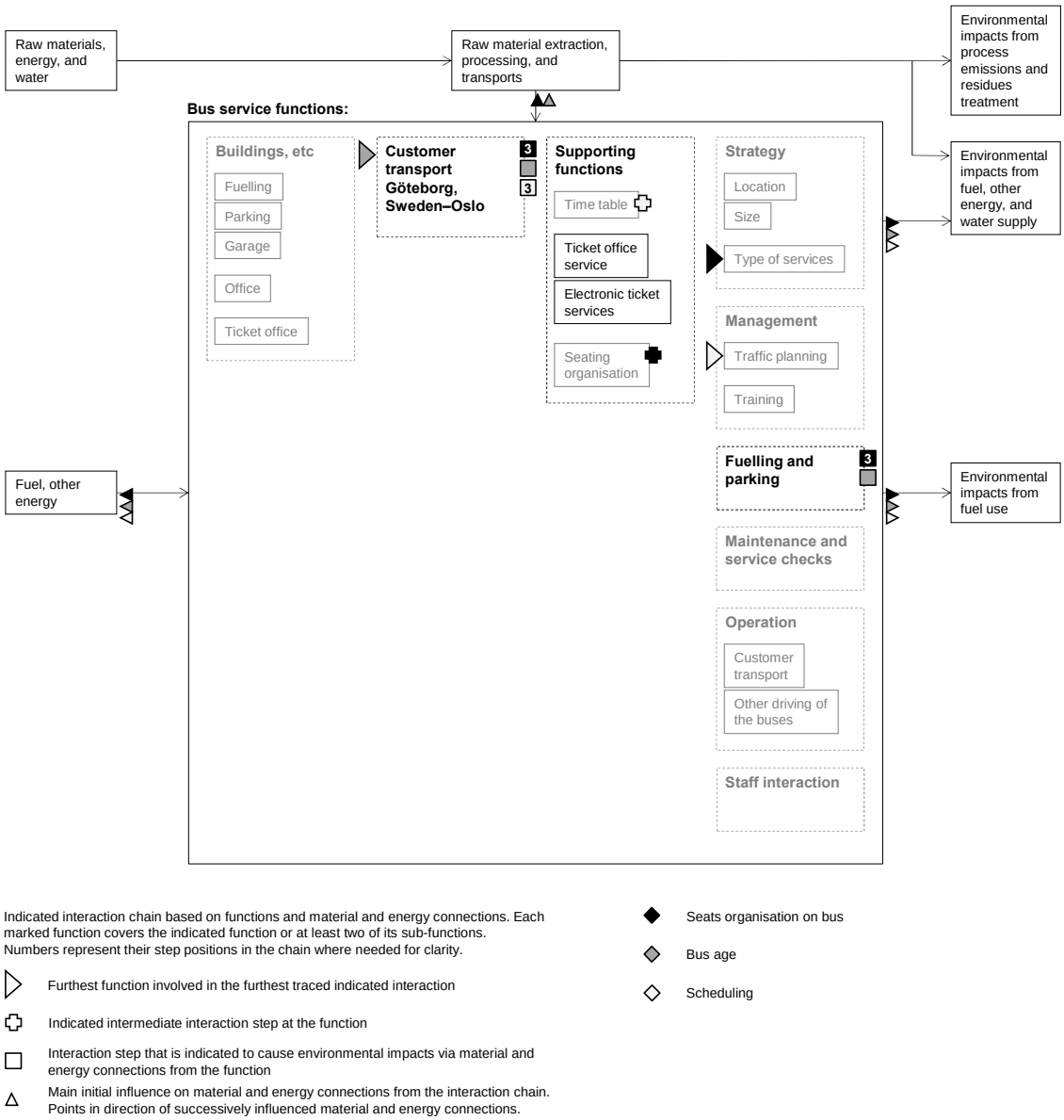


Figure 6.5: Main covered interaction paths connected to the bus fleet management and its organisation that is indicated to influence product life cycle environmental performance

6.8. Analysis and summary of the test case

In this sub-chapter, we present a combination of the outcome of an analysis of and a summary of the previously in this chapter presented nine bus service practices and their indicated potentially significant influence the product life cycle environmental impacts. These environmental impacts were indicated to be moderate from the perspective of environmentally harmful emission and resource use occurring in Northern Europe. The degree of certainty of environmental significance of these practices have been found to generally be moderate, since the bus travel test case mainly is based on on-site observations as customer, a few visits and a combination of a qualitative and quantitative LCA basis. Further, each of the nine practices seem to be connected in not necessarily

discernible ways, mainly not or very weakly but for smaller shares of the potential connections weakly, moderately or strongly. This is outlined for the respective connections in Table 6.6, further on in this sub-chapter. Further, the practices seem to include coverage of ten seemingly generic issues that might to be of environmental relevance for many other activities in society and which seem to cover the main findings for all of the nine practices identified. These ten are operation, training for environmentally less impacting operation, staff interaction, space utilisation, coordination with activities within other product life cycles affected by the organisation, provision of, and type of electronic services, co-location of servicing facilities in relation to the delivery of the main product, age of equipment, and adaptation to activities external to the organisation's product life cycles. The taken together seeming importance of these for understanding the thirteen practices has been found to be none or low mainly and moderate, high, or very high to smaller degrees. This is outlined per issue and per practice in Table 6.7, further on in this sub-chapter.

Table 6.6: Indicated strengths of connections between the covered bus services practices

Indicated environmentally significant practices of the bus service providers. A: Driving style B: Ticket sales C: Fuelling, cleaning, servicing, maintenance and repairs at the garage D: Fleet management	Strength of connection between the practice and the other practices. 0 = no or very weak, 1 = weak, 2 = moderate, 3 = strong								
	A.1	A.2	B.1	B.2	B.3	C.1	D.1	D.2	D.3
A.1 Calmness and smoothness degrees		1	0	0	0	0	0	0	1
A.2 Eco-driving training and discussions degrees			0	0	0	0	0	0	1
B.1 Sales office sizes				3	2	0	0	0	0
B.2 Number of routes served by the ticket offices					0	2	0	0	0
B.3 Use of electronic tickets degree and digital solution chosen for this						0	0	0	0
C.1 Garage location							0	0	0
D.1 Seats organisation differences on the buses								1	0
D.2 Fleet age									0
D.3 Scheduling differences									

Table 6.7: Seeming generic issues and their indicated importance for explaining the covered bus services practices

Seeming generic issues	Indicated importance for explaining the practices. 0 = no or low, 1 = moderate, 2 = high, 3 = very high								
	A. 1	A. 2	B. 1	B. 2	B. 3	C. 1	D. 1	D. 2	D. 3
Operation	3	3	0	0	0	0	0	0	2
Training for environmentally less impacting operation	1	3	0	0	0	0	0	0	0
Staff interaction	1	3	0	0	0	0	0	0	0
Space utilisation	0	0	3	3	2	0	3	0	0
Coordination with activities within other product life cycles affected by the organisation	0	0	1	3	0	0	0	0	0
Provision of electronic services	0	0	0	0	3	0	0	0	0
Type of electronic services	0	0	0	0	3	0	0	0	0
Co-location of servicing facilities in relation to the delivery of the main product	0	0	0	0	0	3	0	0	0
Age of equipment	0	0	0	0	0	0	1	3	0
Adaptation to activities external to the organisation's product life cycles	0	0	0	0	0	0	0	0	3

Further, it seems for a considerable degree of the practices not clear how large environmental impacts a certain state would lead to, and for some of them not clear whether they in a certain state would lead to increased, decreased, or similar product life cycle environmental impacts. Therefore, it seems not possible, based only on the bus travel test case, to make a ranking of environmental performance per functional unit between each of the three compared bakeries and their soft bread product life cycles – a more detailed study is necessary for that. It points to certain green advantages of scale when it comes to servicing and drivers' training for Swebus Express but it also points to certain green advantages owing to the new of buses of GoByBus.

Nevertheless, the presentation based on the screening seems to show that the environmental performance is not easily deduced from distance and bus type, as would be the procedure in standard LCA. Even if no direct quantitative environmental differences were produced, the screening has *at least* shown that the bus companies operated with different business models (affecting passenger-km) and with different approaches to innovation and fleet management

(affecting emissions), and that the environmental impacts per functional unit were indicated to depend on an intertwined interplay of management with technology. This includes, among other:

- Eco-driving training and discussions degrees
- Number of routes served by the ticket offices
- Seats organisation differences on the buses

Further, these and other of the identified practices seem to a small to moderate degree to have been dependent on each other. A thorough nodal LCA organisation study might result in an understanding of how some of these and other practices are related and their magnitudes of influence on environmental performance. A reason why it may not be the result is the seeming relations between the practices for a moderate share of them. Based on the list just prior to this paragraph it was indicated that, for example, number of routes served by the ticket offices was related to garage location. The causes and effects involved in these practices likely to a small to moderate degree were difficult to discern due to several involved causes, additional impacts on environmental performance of these, and that case studies probably only could cover certain specific modes of these practices. On the other hand, such a result seems in itself to be of low to moderate relevance for pointing to the usefulness of searching for complementing approaches to direct changes to the organising for considerably lowering the environmental impacts caused by environmentally ineffective organising. Finally, the ratio between the occurrence of results useful for concrete actions and this pointing towards complementing approaches seems for intercity bus travel with bus routes in Scandinavia as nodes to be little to moderately difficult to predict and the taken together gain of these results have been indicated to be moderate to large compared to using a screening approach. The components and overall findings on this reasoning on choosing between a screening and a thorough nodal LCA organisation study for this product type and this type of nodes is presented in Table 6.8, further on in this sub-chapter.

Table 6.8: Overview of findings from reasoning on differences in usefulness between a screening and a thorough nodal LCA organisation study for intercity bus travel with bus routes in Scandinavia as nodes

Useful findings from the screening nodal LCA organisation study – summary		Business models operated by and innovation and fleet management approaches of the bus travel operator companies differed in ways seem to have influenced environmental performance Identified intertwined interplay between management and technology
Seeming gain of performing instead of screening a thorough nodal LCA organisation study	Environmental performance: Overall	Moderate to small
	Environmental performance: Per part of the system	Moderate to large
	Environmental performance: Over time	Moderate
	Organisational study	Moderate to large
	Producing a basis for carrying out concrete actions	Large to moderate
	Taken together: Magnitude of gain and its predictability based on the screening	Moderate to large gain Moderate to high predictability
	Taken together: Types of gain and their predictability based on the screening	Moderately to largely producing a basis for carrying out concrete actions Little pointing to a need for complementing alternative approaches Moderate to high predictability

Further, it may also be worth considering that bus companies often become door openers for alternative fuels and powertrains. In Sweden, alternative fuels such as ethanol, biogas, etc., were first introduced via bus companies. This could be covered and discussed in a more detailed study.

7. CEMENT (BASED ON TEST CASE 4)

In this chapter, we focus on the in the here reported on project identified organisational practices of indicated product life cycle environmental significance for the physical commodity cement and traced from nodal sites of three by the time of the study operating cement plants in Sweden. The product life cycle environmental impacts of cement production are reported to be very large (see, e.g., Huntzinger and Eatmon, 2009).

7.1. Study objects

7.1.1. Selection of study objects

In Sweden, three cement production plants were in operation at the time of this study, and these were selected as the nodal sites in the cement test case. The LCA approach cradle-to-gate was here used for studying them – covering the product life cycles up and until the processes at the cement plants. In addition, a general approach was used to cement since the test case did not reveal particular differences related to organisational practices between the different types of cement that were produced at the plants studied. Based on this, the functional unit was chosen to be *one kg of cement*.

7.1.2. Data collection

The cement test case is based on one guided tour, a law case file, environmental reports, reports from the company operating the studied plants, and on published material on the characteristics of the environmental impacts related to cement production. The guided tour was a study visit to one of the three studied plants (Skövde), the law case dealt with a production permit for one of the plants (Degerhamn) and the environmental reports covered all of the three plants.

7.1.3. About the three sub-cases

The three plants were located in Slite (Gotland County), Skövde (Västra Götaland County), and Degerhamn (Kalmar County), respectively. The three plants were at the time of the study operated and owned by the company Cementa AB, which in turn was fully owned by the Germany based enterprise HeidelbergCement (Cementa, n.d.). An overview of the plants is also presented in Table 7.1, further on in this sub-sub-chapter.

Table 7.1: Overview of general characteristics of three cement plants

	Slite	Skövde	Degerhamn
Location	Gotland County	Västra Götaland County	Kalmar County
Cement production, Mton 2007 (Cementa, n.d.)	2.0	0.6	0.3

7.2. Life cycle assessment review

Through existing LCAs (Huntzinger and Eatmon, 2009; Vold and Rønning, 1995), guidance can be found on the in the cement test case studied cradle-to-gate product life cycle environmental performance of cement. This is available regarding the share of global as well as Swedish cement production of total global GWP contributions, regarding it compared to the cradle-to-gate product life cycle environmental performance of its subsequent product concrete for cement produced in the Nordic countries, and regarding different environmental impacts for cement.

Of total carbon dioxide emissions, it has been reported that around five percent of the global and around two percent of the ones from Nordic country emissions stem from the cement manufacturing cradle-to-gate product life cycles until and including cement plants (Huntzinger and Eatmon, 2009; Vold and Rønning, 1995, p. 29).

Regarding cradle-to-gate life cycle impacts until and including concrete production, an LCA from 1995 based on average cement produced in the Nordic countries can be used for evaluating this. Different environmental impacts were covered and they were weighted together using the valuation models of BUWAL, EPS, and CML. For each of these three models, more than around 90% of the product life cycle environmental impacts until and including cement production were reported to stem from the taken together impacts of fossil fuel supply, and of the release of mercury (Hg), of CO_2, of sulphur dioxide (SO_2) and of nitrogen oxides (NO_X). The cement cradle-to-gate systems for each of these five environmental categories contributed to more than 85% of the corresponding environmental impacts from cradle-to-gate systems until and including concrete production (Vold and Rønning, 1995, p. 43). Therefore, the in the cement test case used product life cycles that end at the cement manufacturing seem to be valid units of analysis.

Regarding cement cradle-to-gate product life cycle environmental impacts for different environmental categories, the five mentioned ones from the 1995 LCA were used for creating a quantitative overview. Of the in the LCA covered cement cradle-to-gate systems' reported total environmental impact, CO_2 accounted for around 25% when using each of the BUWAL and CML

models, and around 60% when using the EPS model. Further, of these systems' environmental impacts, fossil fuel supply was reported to account for around 5% when using the BUWAL model, around 35% when using the EPS model, and around 15% when using the CML model. Regarding Hg's share of these systems' environmental impacts, it was reported to account for around 20% when using the BUWAL model, and less than 2% when using each of the models EPS and CML, and. The corresponding figured for SO_2 were around 10% when using each of the BUWAL and CML models, and less than 2% when using the CML model, and for NO_X around 30% when using the BUWAL model, less than 2% when using the EPS model, and around 40% when using the CML model. (Vold and Rønning, 1995, p. 36.) Further, the *clinker* baking process, where limestone and other ingredients are baked in an oven and thereby through *calcination* chemically transformed to the cement ingredient clinker, was reported to contribute to more than 75% for each of the cement cradle-to-gate environmental impacts for the five environmental categories here covered (Vold and Rønning, 1995, pp. 33–34). In line with this, Huntzinger and Eatmon (2009) presented the product life cycle CO_2 emissions from global Portland cement production as stemming almost fully from the *clinker* process at the cement plants.

Further, the reported CO_2 emissions per kg cement produced at the Skövde plant increased by around 7% between 2006 and 2007 while the other two Swedish cement plants reported decreases in the corresponding figures of around 9% at the Slite plant and around 11% at the Degerhamn plant, respectively (Cementa n.d.).

Based on the previously in this sub-chapter referred to 1995 LCA publication and on the visit and text material used in the cement test case, functions of seeming relevance in the covered cradle-to-gate cement product life cycles of the test case's three plants have been identified. These functions are included in the graphical presentation in Figure 7.1, further on in this sub-chapter.

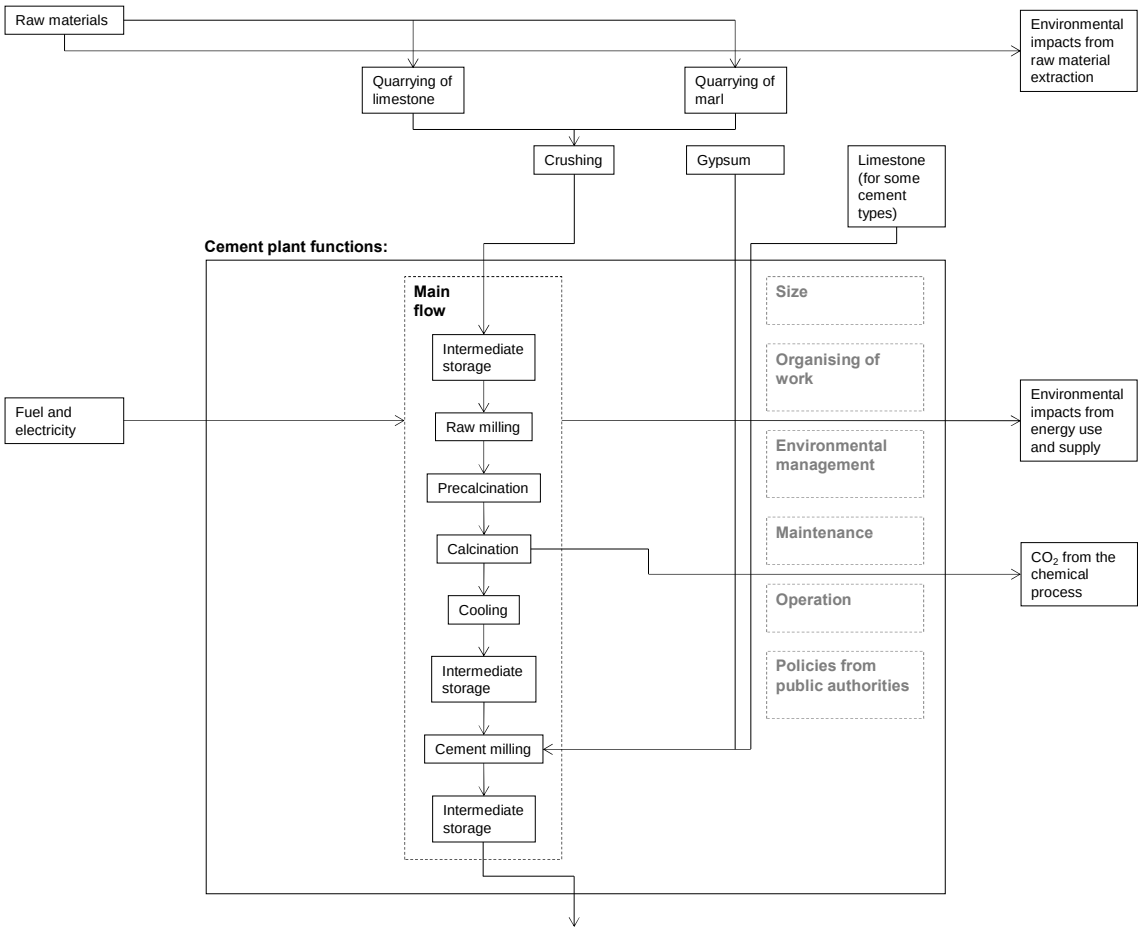


Figure 7.1: Overview of screened indicated product life cycle environmentally significant functions for the three cement plants. Directly through material and energy connections environmentally contributing functions in black, and indirectly contributing ones in grey.

7.3. Socio-material points of interaction at the product life cycles

The socio-material interactions at the product life cycles via which organisational practices have been indicated to cause considerable environmental consequences in the cement test case are connected to negotiations between cement producers and environmental authorities (A), and maintenance and operation of cement plants (B).

7.4. Negotiations between cement producers and environmental authorities (A)

Being major industries, the Swedish cement plants were at the time of the study closely controlled by environmental authorities (cf., e.g., Cementa, 2007, 2008a, b). This included the involvement of environmental authorities when production permits for the plants required renewal. These

permits set the maximum allowed production volume at the plants. Production above this level required a new permit contract to be established. (cf. Växjö Tingsrätt, 2007.)

After negotiations on one such permit that was finalised during June 2007 for the Degerhamn plant, the emissions levels of NO_X were reported to have been quickly lowered from high levels to considerably lower levels. This occurred despite that the company had claimed the emissions level reported to be reached to be definitely uneconomic to attain and despite the permit grant only requesting the company to conduct an investigation of reduction possibilities (Växjö Tingsrätt, 2007, p. 5). The plant was reported to have reached emissions levels of 470 mg/m^3 and 418 mg/m^3 at their two different ovens, respectively, by the end of 2007 (Cementa, 2008a, Textdelen, p. 12), compared to 800 mg/m^3 presented by the company during the permit negotiations as the lowest feasible emissions level (Växjö Tingsrätt, 2007, p. 16). The negotiations seem from the law court file connected to it to have been an iterative process, and therefore the reductions may have been a consequence of this iterative characteristic of the procedure (cf. Växjö Tingsrätt, 2007).

On the other hand, the considerable efforts spent during these negotiations may be a result of them taking place very seldom and of these permits to be renewed only when production levels have reached the upper limit allowed by the current production permit. The previous permit for the plant was issued in 1973 (Växjö Tingsrätt, 2007, p. 6).

See Table 7.2 and Figure 7.2, further on in this sub-chapter, for summaries of the outlined types of negotiations with authorities and their indicated environmental significance.

Table 7.2: Negotiations between cement producers and environmental authorities (A)

	Slite	Skövde	Degerhamn
The renewal procedure for production permits may increase the possibility for changes to less environmental impacts from the plant through being thorough, consisting of several iterations, and being over time extended	-	-	According to law file repeatedly reiterated and prolonged negotiations with environmental authorities in 2007. Shortly after the negotiations, the plant was reported to have lowered its NO_X emissions to lower levels than requested by the authorities.
The conditions for these permit renewals to occur may influence environmental performance	-	-	Several decades had passed since the previous renewal, which may make each negotiation more effective for lowering environmental impacts, but the effect on average per time unit ought to be the factor studied. Seems currently only to be renewed if production volumes have increased significantly since the last permit was authorised.
➔ A more detailed study of the negotiations between the cement producers and the authorities may reveal environmental impacts differences between the three studied cement plants' product life cycles.			

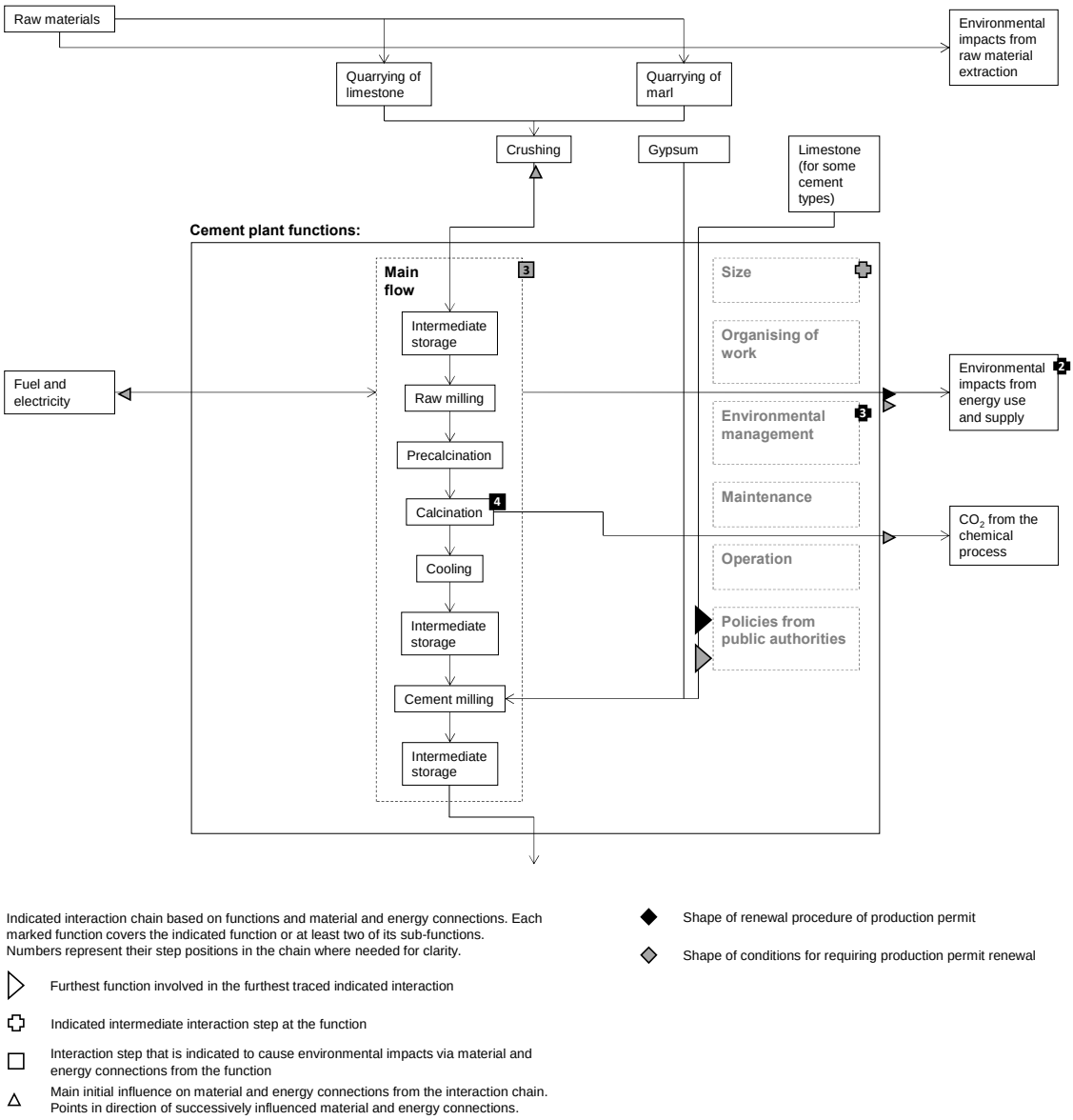


Figure 7.2: Main covered interaction paths connected to the negotiations with authorities that are indicated to influence product life cycle environmental performance

7.5. Maintenance and operation of cement plants (B)

A minimisation of malfunctioning and an optimisation of operation of the Skövde cement halts was indicated to have considerable influence on product life cycle environmental performance. Such malfunctioning and not well working operation of the plant can result in ineffective use of inputs and in not producing cement of good enough quality. The reported CO_2 emissions per kg cement produced at the Skövde plant increased by around 7% between 2006 and 2007 while the other two Swedish cement plants reported decreases in the corresponding figures of around 9% at the Slite plant and around 11% at the Degerhamn plant, respectively (Cementa n.d.). At the in cement test case visited plant in Skövde, the maintenance routines were said to have been changed

from an uncoordinated state to being based on daily coordination meetings. It was said that this occurred in late 2007, at the time of the identified comparably large increase in CO_2 emissions at the Skövde plant compared to at the other Swedish cement plants. It was explained as being triggered by a technical breakdown. (Sjöstrand, per. comm. 2009.)

See Table 7.3 and Figure 7.3, further on in this sub-chapter, for summaries of the outlined types of aspect on maintenance planning and their indicated environmental significance.

Table 7.3: Maintenance and operation of cement plants (B)

	Slite	Skövde	Degerhamn
Handling of technical problems at the plant which relates to avoiding unnecessary malfunctioning and to optimise operation of the plant, in order to use inputs effectively and produce cement of enough quality to be sold	-	It was said that the maintenance routines changed from an uncoordinated state to being based on daily coordination meetings. This change was explained as being triggered by a technical breakdown.	-
➔ A more detailed study of the maintenance and operation of the plants, their connections to effective use of inputs and to the ability of producing cement of high enough quality may reveal environmental impacts differences between the three studied cement plants' product life cycles.			

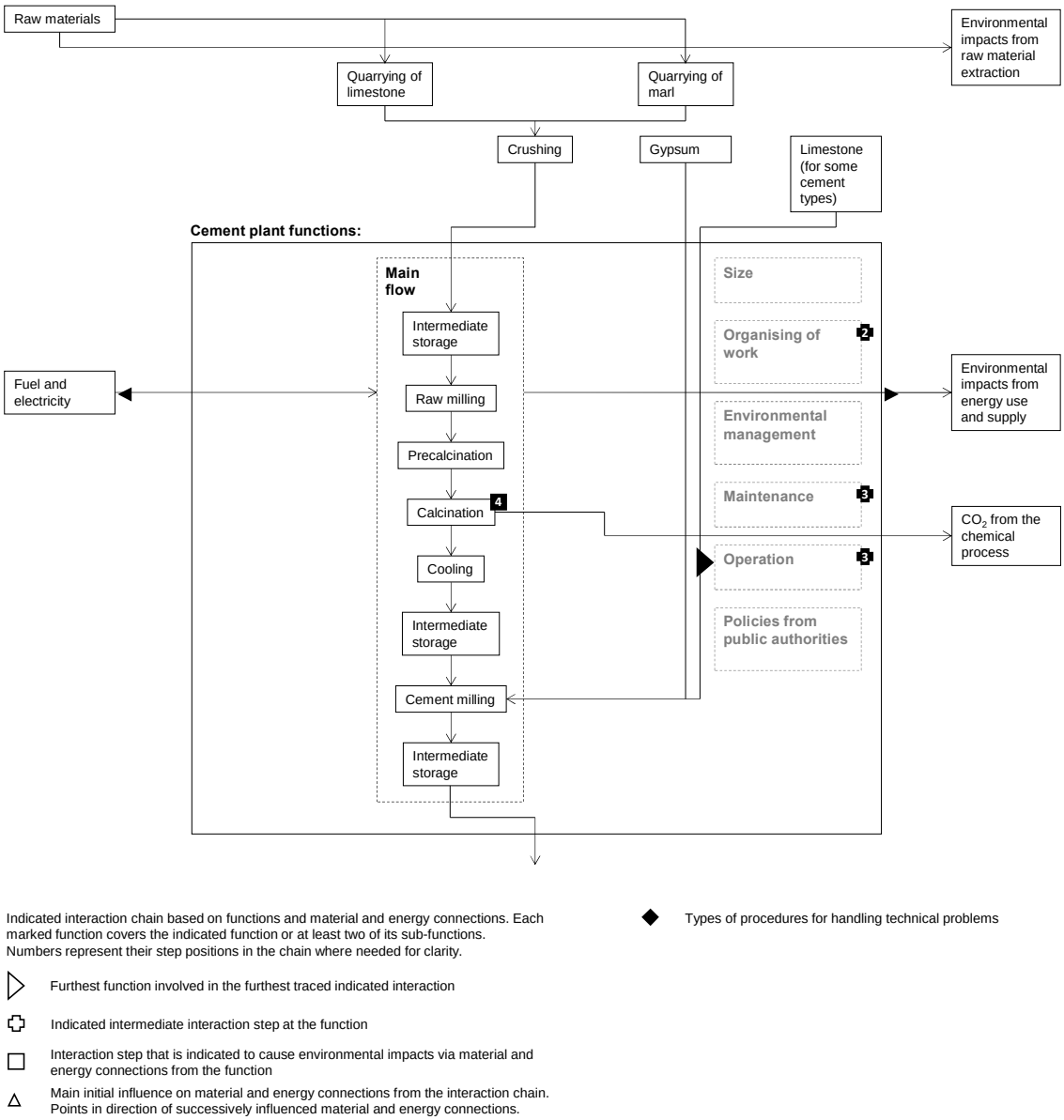


Figure 7.3: Main covered interaction paths connected to the maintenance and operation of the plants that are indicated to influence product life cycle environmental performance

7.6. Analysis and summary of the test case

In this sub-chapter, we present a combination of the outcome of an analysis of and a summary of the previously in this chapter presented three cement production practices and their indicated potentially significant influence the product life cycle environmental impacts. These environmental impacts were indicated to be very large from the perspective of environmentally harmful emission and resource use occurring globally. The degree of certainty of environmental significance of these practices have been found to lie around moderate, since the practices and their indicated environmental impacts were identified mainly via a study visit, and some to

authorities reported quantifications of emissions and to environmental performance seemingly tightly connected characteristics. Further, two of the three practices seem to be connected to each of the other strongly while the third practice seems not to be connected to them, and all of these connections are necessarily not discernible. This is outlined for the respective connections in Table 7.4, further on in this sub-chapter. In addition, the practices were indicated to be dependent on the product characteristics of one process to a very large degree dominating environmental impacts, and already high levels of environmental regulation and pressure on the production of the product. Further, the practices seem to include coverage of six seemingly generic issues that might to be of environmental relevance for many other activities in society and which seem to cover the main findings for all of the three practices identified. These six are repeated interaction, types of instruments used when thorough demands are made by environmental authorities, length of time between thorough environmental demands, flexibility of what the work force performs, coordination of work force, and a crisis leading to changed organisational practices. The taken together seeming importance of each of these for understanding each of the three practices is none or low or very high to considerable degrees, and high to a small degree. This is outlined per issue and per practice in Table 7.5, further on in this sub-chapter.

Table 7.4: Indicated strengths of connections between the covered cement production practices

Indicated environmentally significant practice. A: Negotiations between cement producers and environmental authorities B: Maintenance and operation of cement plants	Strength of connection between the practice and the other practices. 0 = no or very weak, 1 = weak, 2 = moderate, 3 = strong		
	A.1	A.2	B.1
A.1 Production permits renewal procedure differences: May decrease environmental impacts from the plant through being thorough, consisting of several iterations, and being over time extended		3	0
A.2 Production permit expiration criteria differences: May influence environmental performance			0
B.1 Organisational practices for handling technical problems at and operation of the plant differences: Relates to avoiding unnecessary malfunctioning and to optimise operation of the plant, in order to use inputs effectively and produce cement of enough quality to be sold			

Table 7.5: Seeming generic issues and their indicated importance for explaining the covered cement production practices

Seeming generic issues	Indicated importance for explaining the practices. 0 = no or low, 1 = moderate, 2 = high, 3 = very high		
	A.1	A.2	B.1
Repeated interaction	3	2	3
Types of instruments used when thorough demands are made by environmental authorities	3	2	0
Length of time between thorough environmental demands	2	3	0
Flexibility of what the work force performs	0	0	3
Coordination of work force	0	0	3
A crisis leading to changed organisational practices	0	0	3

Further, it seems in general for the three practices not clear whether they in a certain state would lead to increased, decreased, or similar product life cycle environmental impacts. Therefore, it seems not possible, based only on the cement test case, to rank the three cement plants studied regarding environmental performance per kg cement produced – a more detailed study is necessary for that.

Nevertheless, the presentation based on the screening seems to show that the environmental performance and its causes are not pictured in a way that is practically useful from the material and energy input to the cement plants and its output volumes, as would be the procedure in standard LCA. Even if no direct quantitative environmental differences were possible and feasible to present, the screening has *at least* shown that the cement plants seemed to be subject to organisational processes that influenced environmental performance (affecting effectiveness of maintenance, operation and environmental management). The screening also seems to have shown that the environmental performance connected to cement production depends on an intricate interplay of organisational practices with technology and material and energy. This consists of:

- Production permits renewal procedure differences and its environmental impact through the level of actions at cement plants resulting in reductions of environmental impacts
- Production permit expiration criteria differences and its environmental impacts through the frequency of actions at cement plants resulting in reductions of environmental impacts

- Organisational practices for handling technical problems at and operation of the plant differences and environmental impacts through influence on effectiveness of inputs use and on producing cement of enough quality to be sold

Further, and although it is based only on a small number of practices and therefore is difficult to draw conclusions from two of these practices seem to have been considerably dependent on each other. A thorough nodal LCA organisation study might result in an understanding of how some of these and other practices are related and their magnitudes of influence on environmental performance. A reason why it may not be the result is the seeming intricate relations between the practices for a majority of them. The practice on the production permits' expiration criteria seemingly depended on organisational practices for handling technical problems at and operation of the plant differences. These causes and effects likely to a moderate to high degree were difficult to discern due to the intricately involved causes, and that case studies probably only could cover certain specific modes of these practices. On the other hand, such a result seems in itself to be moderately relevant for pointing to the usefulness of searching for complementing approaches to direct changes to the organising for considerably lowering the environmental impacts caused by environmentally ineffective organising. Finally, the ratio between the occurrence of results useful for concrete actions and this pointing towards complementing approaches seems for cement product life cycle environmental performances with cement plants in Sweden as nodes to be moderately to highly difficult to predict. Further, the taken together gain of these results have been indicated to be moderate to high compared to using a screening approach, partly due to the small number of practices identified in the cement test case. The components and overall findings on this reasoning on choosing between a screening and a thorough nodal LCA organisation study for this product type and this type of nodes is presented in Table 7.6, further on in this sub-chapter.

Table 7.6: Overview of findings from reasoning on differences in usefulness between a screening and a thorough nodal LCA organisation study for cement product life cycle environmental performances with cement plants in Sweden as nodes

Useful findings from the screening nodal LCA organisation study – summary		Organisational processes differences seem to have influenced environmental performance Identified intricate interplay between organising, technology, and materials and energy processes
Seeming gain of performing instead of screening a thorough nodal LCA organisation study	Environmental performance: Overall	Small
	Environmental performance: Per part of the system	Moderate to large
	Environmental performance: Over time	Moderate to large
	Organisational study	Moderate to large
	Producing a basis for carrying out concrete actions	Moderate
	Taken together: Magnitude of gain and its predictability based on the screening	Moderate to large gain Moderate predictability
	Taken together: Types of gain and their predictability based on the screening	Moderately producing a basis for carrying out concrete actions Moderately pointing to a need for complementing alternative approaches Moderate to low predictability

Further, it may also be worth mentioning that the significant pressures on reducing environmental impacts from cement production might have resulted in the mainly technical measures for this purpose already have become carried through to a degree where few more economically feasible such initiatives can be found. This might also have resulted in a view on this product as already fully optimised from an environmental point of view. Therefore, the approach used in the cement test case could provide further elsewhere not easily found and unexpected potential reductions of its environmental impact.

8. PROPERTIES MANAGEMENT (BASED ON TEST CASE 5)

In this chapter, we focus on through two existing publications identified organisational practices of indicated product life cycle environmental significance for the service residential properties management and traced from nodal sites of four residential properties in Gothenburg, Sweden. Properties constitute a large share of the construction sector, and this sector in Sweden has been reported to use 40% of the energy and materials used annually (BYKR, 2001, cited in Brunklaus, 2008; OECD, 2003, cited in Brunklaus, 2008). The empirical data that this chapter is based on was originally presented in publications by Birgit Brunklaus (2008, Paper III, 2009a).

8.1. Study objects

8.1.1. Selection of study objects

Four different residential estates or sets of estates are the nodal sites that the here reported on and further analysed publications covered and which are used as the basis in this chapter. It is reported that, in order to focus the studies on the organisational aspects, these four were chosen in order to minimise differences between them regarding technical, climate, and tenant conditions. All of the four were reported to cover 'County Governor' style buildings (in Swedish 'landshövdingehus') initially constructed in the 1920s and 1930s that were located in the city district Majorna, in Gothenburg, Sweden. These estates and estates sets were reported on in two separate publications that each compared two of them. The first of these two publications (account I) reported that the estates it covered regarding tenant conditions both were of the size of approximately 100 flats each. The publication reports that it compared one estate operated by one organisation (HSB study) with three different estates operated by another organisation (Fambo study). Considering the same parameter, the second of the two publications (account II) reported that it compared estates with around 15 flats each. The publication reported to compare one estate operated by one organisation (Dalavik study) with two estates operated by another organisation (Wallenstam study). The reason for studying estates with the lower number of flats was presented to be that the organisations targeted owned smaller units in the Majorna area that was selected as the location for the study objects. (Brunklaus, 2008, pp. 26–27, Paper III, p. 4, 2009a, p. 122.)

It can be said that proxies for functional units were used in the publications here reported on through covering energy (kWh) and water use (L) and relating both of them to the number of square metres of floor area. (cf. Brunklaus, 2008, Paper III, p. 3, 2009a, p. 122.)

8.1.2. Data collection

Account I reports that the HSB study was based on ten days of observation and seven face-to-face interviews, in 2003, and document studies. The Fambo study is reported to be based on eight days of observation and twelve face-to-face interviews, in 2003 as well, and document studies. (Brunklaus, 2009a, p. 123) Account II reports that the Dalavik study is based on three days of observation, two face-to-face interviews, and two telephone interviews, in 2006 and 2007, and document studies, and that the Wallenstam study is based on four days of observation, four face-to-face interviews, and four telephone interviews, in 2006 and 2007 as well, and document studies. (Brunklaus, 2008, Paper III, p. 4.)

8.1.3. About the four sub-cases

Account I reports that the HSB study covered the organisation of the by tenants cooperatively managed estate 'HSB Svärdsliljan'. According to the publication, each flat of this estate was owned by its tenant or tenants, and the estate's infrastructure was managed by the estate's organisation. The organisation was reported to be a member of the federal umbrella organisation HSB, to which around 35,000 flats in Gothenburg were reported to be associated. The local organisation was described as being independent of the nationwide HSB organisation, and being subject to a high degree of freedom regarding how to manage its estate. However, it was also reported that assistance and expertise on managerial aspects could be provided from HSB centrally, if requested. (Brunklaus, 2008, p. 26, 2009a, pp. 122, 132.)

The Fambo study was reported to cover estates operated by the municipally owned property company 'Familjebostäder'. Familjebostäder was described as owning and managing around 18,000 flats. It was reported that it consisted of a few large districts and that each of these districts' work organisation was specialised. Further, the publication on the Fambo study reported that Familjebostäder had been performing environmental work since at least the late 1970s. (Brunklaus, 2008, p. 26, 2009a, pp. 122, 132.)

Account II reports that the organisations studied through each of the Dalavik and Wallenstam studies were private companies conducting real estate management. Dalavik was described as having owned and managed a few properties in Gothenburg since the early 1990s. It was presented that its main business earlier was shipping at a small scale and that the company's properties management was based on this experience. In addition, the company chair was described as exercising an overarching and coordinative role in relation to her employees and the properties.

Wallenstam was described as having originally been a construction company that had been conducting properties management since the middle of the 1980s. It was reported that they at the time of the Wallenstam study owned and managed around 2,800 flats in Gothenburg and that the

estates here covered had been managed by them since the early 1990s. In 2000, environmental work was presented as having been introduced in the company. (Brunklaus, 2008, p. 27.)

In Table 8.1, further on in sub-sub-chapter, an overview is given of these presented and some additional reported characteristics, which give the frame for the four here reported on sub-cases.

Table 8.1: Overview of general characteristics of the four properties management services

	Comparative study of estates with around 100 flats each		Comparative study of estates with around 15 flats each	
	HSB	Fambo	Dalavik	Wallenstam
Name of organisation	HSB Svärdsliljan	Familjebostäder	Dalavik	Wallenstam
Parent organisation	Member of the nationwide umbrella organisation HSB	The municipality	-	-
Ownership of organisation	Cooperatively run by the tenants of the estate	Municipally run company	Private company	Private company
Ownership of the flats	Tenant or tenants in each flat	The property management organisation	The property management organisation	The property management organisation
Number of flats managed in Gothenburg	By all HSB members: 35,000	18,000	4 small estates	2,800
Start of the organisation's management of the estate(s)	1927	-	Early 1990s	Early 1990s
Main business prior to properties management	-	-	Shipping	Construction
Organisational characteristics	The organisation was largely independent of the nationwide HSB, but could request their assistance and guidance	Familjebostäder was divided into a few large districts that each had their specialised work organisation	The management of properties was based on shipping management while the company chair had the mandate to control the properties management staff	-
Environmental work since	-	At least since the late 1970s	-	2000

8.2. Aspects connected to life cycle assessment considerations

In the environmental properties management publications here reported on and analysed, energy and water use in the properties was the environmentally impacting materials and energy handling considered, as mentioned. The energy and water services covered in the publications were regarding energy indoor heating and heating of tap water, and regarding water tap water provision, respectively. Both average consumption levels and the variation of consumption levels were covered as environmentally significant parameters. Further, previously quantified influences on energy and water use by different types of appliances and building options (published in 1997) were reported as used as a basis in the publications by Brunklaus. It was reported that these quantifications were used for each of the main types of energy-based services and water-based services, and that environmentally significant practices were traced via key appliances and to these closely related building options. Their characteristics, operation, maintenance and replacements were considered according to the publications. Regarding energy services, this covered the energy supply systems (e.g., the use of heat pumps), windows, insulation, and ventilation. Regarding water based services, this covered supply pipes and drainage, toilets, water taps, and washing machines. (Brunklaus, 2008, Paper III, pp. 129–131, 2009a, pp. 10–13.)

The management practices reported on as being related to these appliances and building options are in this analysis of the properties management publications included in an LCA based overview through their presented related additional building functions. These functions are renovation, fire protection, sound protection, flat level standards, cultural heritage, and the keeping of windows and doors open.

The basic LCA related material and energy connections including the mentioned functions thereby identified are outlined in Figure 8.1, further on in this sub-chapter.

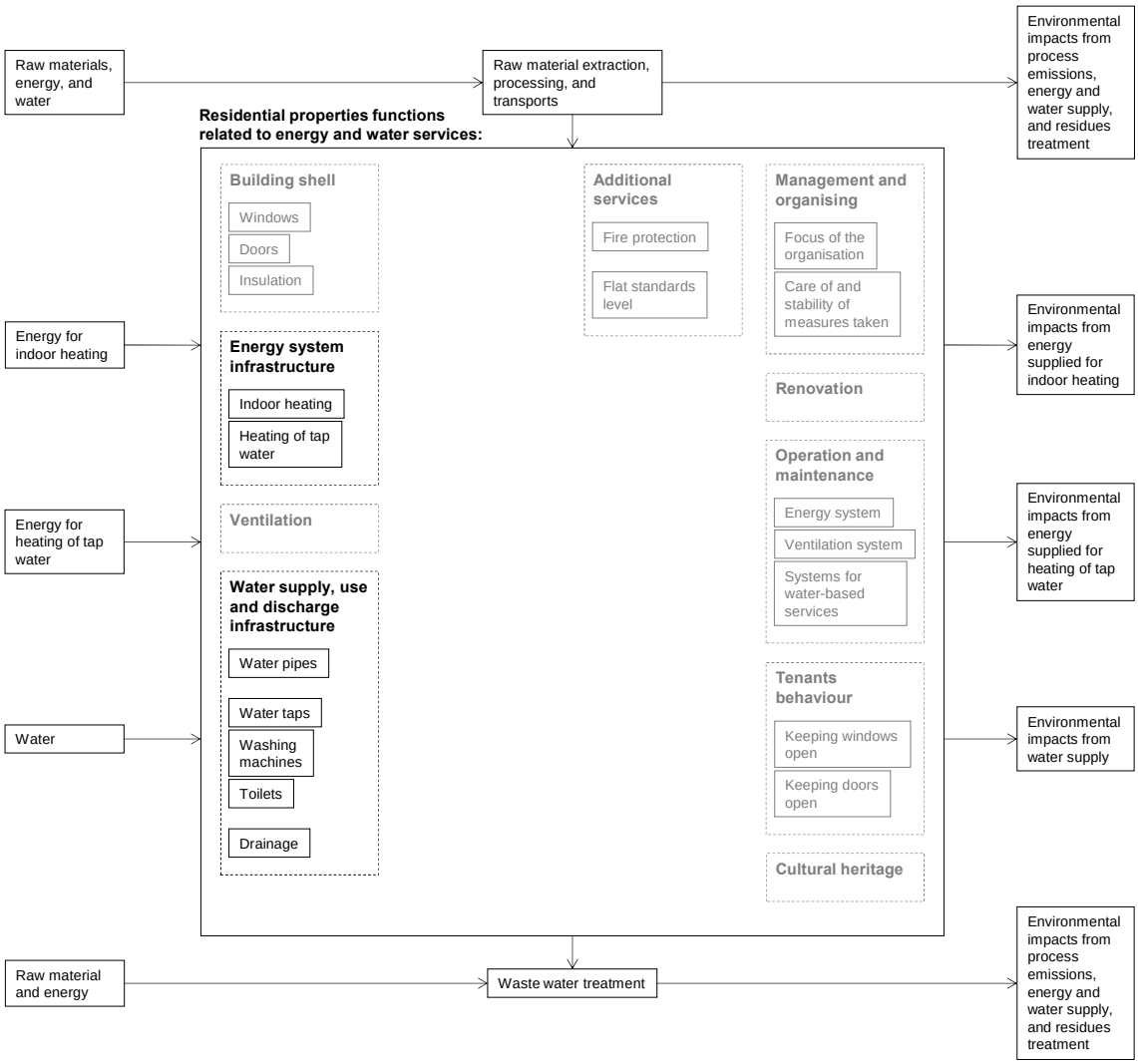


Figure 8.1: Overview of indicated product life cycle environmentally significant functions for the four properties management services. Directly through material and energy connections environmentally contributing functions in black, and indirectly contributing ones in grey.

8.3. Socio-material points of interaction at the product life cycles

Groups of interaction points are used in the here covered publications and these are used for the presentations in this chapter for the practices where differences were presented between the in the publications compared organisations. The groups used in this chapter's presentations cover for energy services windows and doors (the latter only regarding the Dalavik and Wallenstam studies) (1), and insulation, ventilation and energy systems (the latter only regarding the HSB and Fambo studies) (2), respectively. For energy service, they also as one group but only regarding the HSB and Fambo studies cover operation of energy systems and operation of ventilation systems (3). For water-based services, they cover toilets (1), water taps (2), and washing machines (only

regarding the HSB and Fambo studies), water supply pipes and draining system (only regarding the HSB and Fambo studies).

These interactions are in the following covered separately for energy and water services, respectively, and for account I and account II, respectively. First, the interactions reported theoretically to lead to significant environmental performance differences for energy-based services are covered regarding the HSB and Fambo studies (A) and regarding the Dalavik and Wallenstam studies (B), respectively. Then, the corresponding interactions reported for water-based services are covered regarding the HSB and Fambo studies (C) and regarding the Dalavik and Wallenstam studies (D), respectively.

8.4. Energy-based services and their management, according to account I on HSB and Fambo (A)

The reported theoretical differences in environmental impacts between the HSB and Fambo estates regarding energy-based services and the organisational practices connected to them, are in this sub-chapter presented.

Regarding windows, the use of double or triple glazed windows was reported to be environmentally significant. The role of cultural heritage considerations and conflicts for the studied estates were stated to be a driving factor. It is described that a solution had been found that enabled triple glazing while fulfilling the cultural heritage requirements in the HSB estate. This windows difference was concluded to result in a theoretically 5–10% lower energy demand in the HSB estate than in the Fambo estates. (Brunklaus, 2009a, pp. 127, 130.)

Differences between the HSB estate and the Fambo estates were reported to have existed regarding practices that influenced insulation, ventilation, and energy systems. In the HSB estate, it was described that when renovations were performed these were based on requirements to decrease energy use. It was reported that this approach led to adding of attic insulation and mechanical ventilation, and to the installation of a heat recovery system and a heat pump. Regarding the Fambo estates, it was reported that renovations were performed on a cyclic basis. It is described that energy requirements were in focus in Fambo's renovations during the 1980s but not when the three studied estates were renovated in the 1970s. Fambo rationalisations during the 1990s were reported to have led to viewing energy aspects as too time consuming to focus on and that the focus instead was directed towards increasing the level of standards of the flats. These characteristics were concluded theoretically to result in lower energy demands in the HSB estate than in the Fambo estates by 5–10% due to the insulation, by 10–15% due to the ventilation, and by 10–15% due to energy systems. (Brunklaus, 2009a, pp. 126, 130.)

Finally, regarding operation of energy and ventilation systems in account I, the types of scheduling of checks and adjustments of these systems were presented as environmentally

significant. It was reported that these measures were performed continuously in the HSB estate. The mentioned reported on rationalisations in Fambo in the 1990s, on the other hand, had according to account I led to a pre-defined schedule for Fambo's monitoring of their different properties and a procedure where actions only were only carried out in properties were energy consumption had risen to critical levels. These differences were concluded to result in a theoretically lower variation in consumption levels in the HSB estate than in the Fambo estates. (Brunklaus, 2009a, p. 130.)

It was concluded that all these differences in the energy-based services and their management could explain from energy use reports extracted figures on energy use levels (Brunklaus, 2009a, p. 129). It was reported that the HSB estate according to these figures during 1995–2002 used around 30% less energy on average than and experienced less variations in energy use than the Fambo estates used and experienced during 1992–2002 (Brunklaus, 2009a, p. 123). It was presented that the consumption averages reported on were found to result from the effects of a management that was adopted to building characteristics at the HSB estate and of time constraints, and a focus on tenant demands at Fambo. It was presented that the consumption variations reported on were found to result from a caring and stable organisation of operation being deployed at the HSB estate and from a use of an emergency-driven approach at Fambo. (Brunklaus, 2009a, p. 129.)

See Table 8.2 and Figure 8.2, further on in this sub-chapter, for summaries of the described reported on types of energy-based services characteristics and management at the HSB and Fambo estates and the indicated environmental significance of these conditions.

Table 8.2: Reported energy-based services and their management in the HSB estate and the Fambo estates resulting in differences in environmental performance (A) (adapted with minor modifications from Brunklaus, 2009a, p. 130)

	HSB	Fambo
Windows: installation of double or triple glazed windows in relation to cultural heritage demands reported to theoretically lead to 5–10% lower energy use in the HSB estate than in the Fambo estates	It was reported that triple glazed windows were installed after finding a method for combining it with the heritage related demands.	It was reported that double glazed windows were used due to cultural heritage conflicts where triple glazing was disapproved.
Insulation, ventilation, energy systems: insulation, mechanical ventilation, and energy systems in relation to energy demands in renovation reported to theoretically lead to 5–10%, 10–15%, and 10–15% lower energy use, respectively, in the HSB estate than in the Fambo estates	It was reported that energy demands in renovation had resulted in adding of attic insulation and mechanical ventilation, and installation of a heat recovery system and a heat pump.	It was reported that renovations were performed on a cyclic basis, and that energy consumption levels were in focus during Fambo renovations in the 1970s but not when these properties were renovated in the 1980s. It was also reported that Fambo rationalisations in the 1990s led to considering energy requirements as too time consuming to focus on at the same time as increased flat standards levels became prioritised.
Operation of energy system and ventilation: reported to theoretically lead to less variation in energy use in the HSB estate than in the Fambo estates	It was reported that checks and adjustments were made continuously.	It was reported that Fambo rationalisations in the 1990s led to using a pre-defined schedule for monitoring the properties, and that actions were only carried out were energy consumption had risen to critical levels.
➔ Taken together, these differences were concluded to account for the on average around 30% lower and less varying energy use figures presented for the HSB estate during 1995–2002 than for the Fambo estates during 1992–2002. It was presented that the energy use averages were found to result from a management based on adaptation to building conditions at the HSB estate and from time constraints and a focus on tenant demands at Fambo. It was presented that the difference in energy use variation in the studies had been found to result from a caring and stable organisation of operation at the HSB estate and Fambo's use of an emergency-driven approach.		

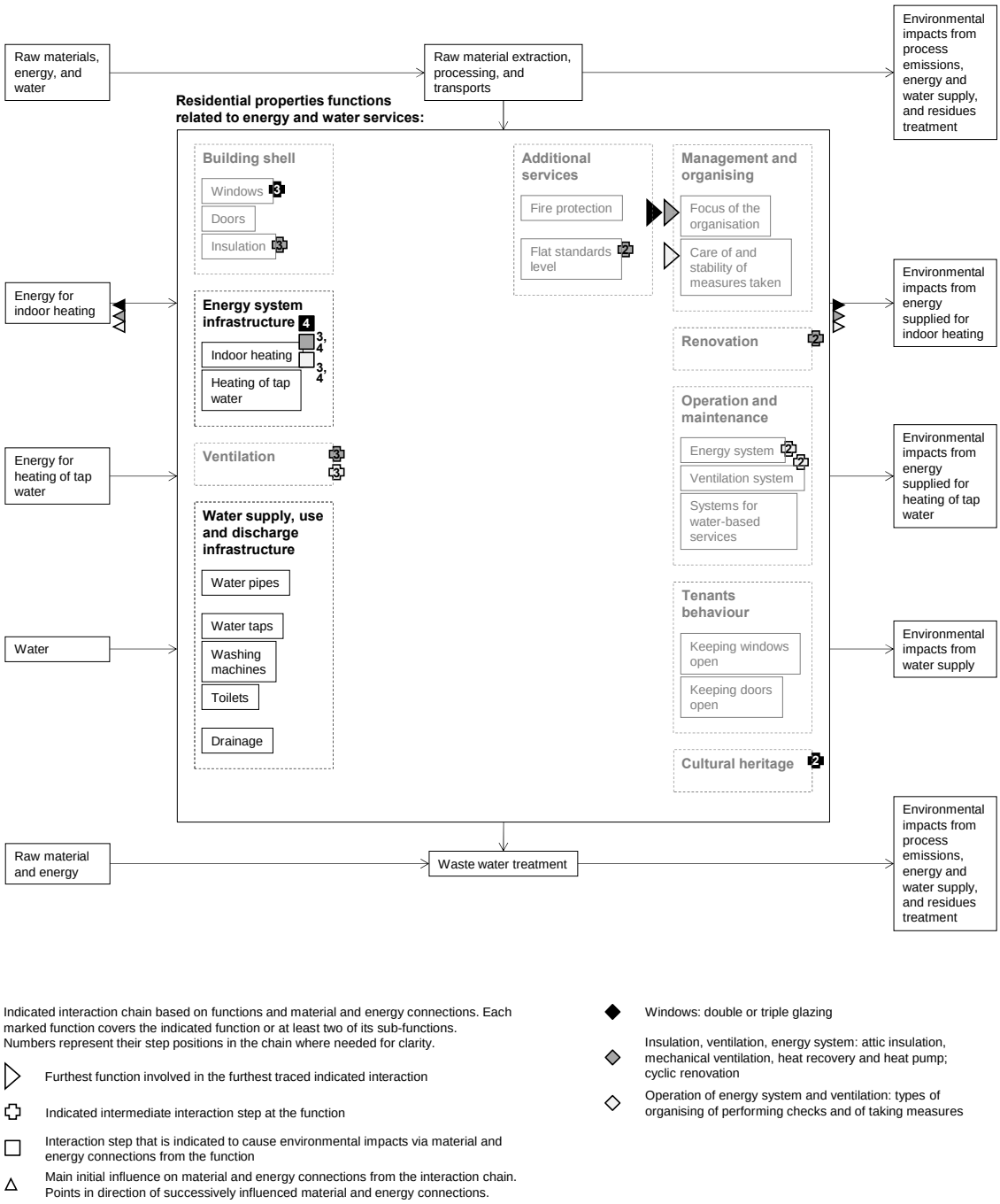


Figure 8.2: Main interaction paths connected to the reported on management with indicated significant influence on product life cycle environmental performance of energy-based services in the HSB and Fambo estates

8.5. Energy-based services and their management, according to account II on Dalavik and Wallenstam (B)

The reported theoretical differences in environmental impacts between the Dalavik and Wallenstam estates regarding energy-based services and the organisational practices connected to them, are in this sub-chapter presented.

Regarding windows and doors, the degree to which these were kept open was reported to be of potential environmental significance between the Dalavik and Wallenstam estates. The tenant at the Dalavik estate were described as keeping their windows and doors more open than the tenants of the Wallenstam estates. This was concluded theoretically to result in 5% lower energy demand in the Wallenstam estates than in the Dalavik estate. (Brunklaus, 2008, Paper III, p. 11.)

It was also reported that environmentally relevant differences between the estates were identified regarding insulation. It was presented that no extra insulation had been added in the Dalavik estate while fire protection concerns had resulted in internal insulation being added in the Wallenstam estates in 1975. It was concluded that the energy use at the Wallenstam estates theoretically was as much as 30% lower than it was at the Dalavik estate, due to this difference. (Brunklaus, 2008, Paper III, p. 11.)

Finally, regarding ventilation, it was reported that the year of installation of the, at the time of the studies, systems for ventilation were indicated to be of environmental significance. It was described that the Dalavik system was installed in 1992 and concluded that this resulted theoretically in as much as 5% lower energy use than the 1975 systems in the Wallenstam estates. (Brunklaus, 2008, Paper III, p. 11.)

It was concluded that all these differences in the energy-based services and their management could explain from energy use reports extracted figures on energy use levels (Brunklaus, 2008, Paper III, p. 12). It was reported that the Wallenstam estates were using around 30% less energy on average during 1997 and 1999–2005 than the Dalavik estate during 1993–2005 (Brunklaus, 2008, Paper III, pp. 5–6, 11). It was reported that this difference was found to result from a management based on a professional type of organising that was adapted to buildings at the Wallenstam estates, and from a self-made management style and economic constraints conflicting with tenant demands at Dalavik (Brunklaus, 2008, Paper III, p. 14).

See Table 8.3 and Figure 8.3, further on in this sub-chapter, for summaries of the described reported on types of energy-based services characteristics and management at the Dalavik and Wallenstam estates and the indicated environmental significance of these conditions.

Table 8.3: Reported energy-based services and their management in the Dalavik estate and the Wallenstam estates resulting in differences in environmental performance (B) (adapted with minor modifications from Brunklaus, 2008, Paper III, p. 11)

	Dalavik	Wallenstam
Windows and doors: to which degree tenants keep these open reported to theoretically lead to 5% less energy use in the Wallenstam estates than in the Dalavik estate	Reported to be open to higher degree.	Reported to be open to lower degree.
Insulation: differences in insulation use reported to theoretically lead to as much as 30% less energy use in the Wallenstam estates than in the Dalavik estate	It was reported that no insulation was added.	It was reported that, due to concerns for fires, internal insulation was added in 1975.
Ventilation: difference in year of installation reported to theoretically lead to as much as 5% lower energy use in the Dalavik estate than in the Wallenstam estates	Reported to be from 1992.	Reported to be from 1975.
➔ Taken together, these differences were concluded to account for the on average around 30% lower energy use figures presented for the Wallenstam estates during 1997 and 1999–2005 than for the Dalavik estate during 1993–2005. It was presented that the energy use averages were found to result from a management based on a professional type of organising that was adapted to buildings at the Wallenstam estates, and from a self-made management style and economic constraints conflicting with tenant demands at Dalavik.		

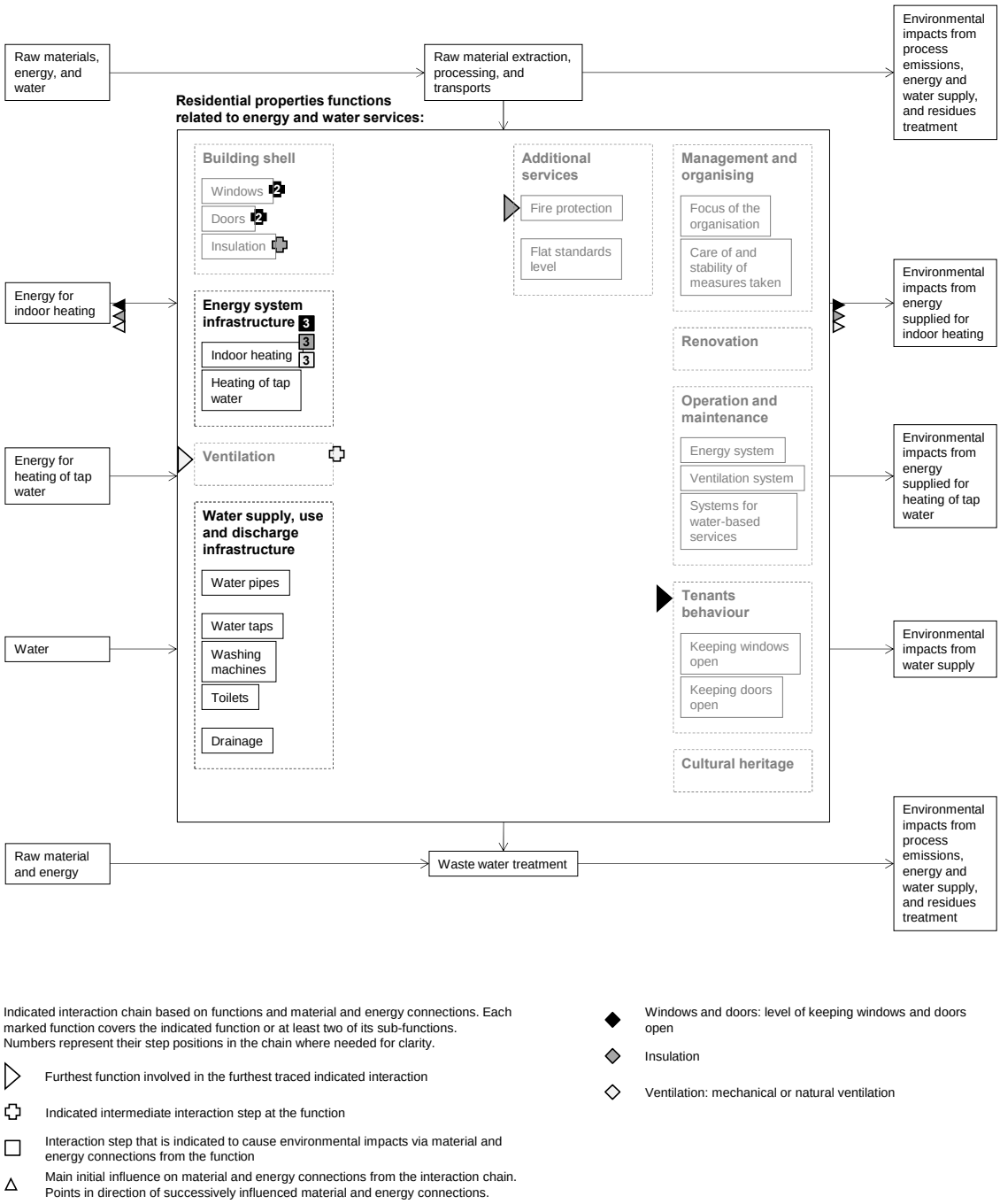


Figure 8.3: Main interaction paths connected to the reported on management with indicated significant influence on product life cycle environmental performance of energy-based services in the Dalavik and Wallenstam estates

8.6. Water-based services and their management, according to account I on HSB and Fambo (C)

The reported theoretical differences in environmental impacts between the HSB and Fambo estates regarding water-based services and the organisational practices connected to them, are in this sub-chapter presented.

Regarding toilets, it was reported that potentially environmentally significant differences were found regarding low-flush toilets, knowledge about the systems, and operation and maintenance. It was described that changing to low-flush toilets was not part of renovation in the HSB estate, and that this type of toilets had been installed in parts of the Fambo estates after emergencies. Further, it was reported that the knowledge about the system and about its recent water use was good and that maintenance was performed when needs appeared in the HSB estate, and that Fambo rationalisations during the 1990s had led to a low prioritising of performing checks and of small repairs. These characteristics were concluded theoretically to result in as much as 12% higher but less varying water use levels in the HSB estate than in the Fambo estates. (Brunklaus, 2009a, p. 131.)

Regarding water taps, it was reported that potentially environmentally significant differences were found in the use of single handle mixers, the knowledge about the systems, and in the operation and maintenance. It was reported that single handle mixers were installed through renovation in the 1980s in the HSB estate, and that they had been installed in parts of the Fambo estates after emergencies. Further, it was described that the knowledge about the system and about its recent water use was good and that maintenance was performed when needs appeared in the HSB estate, and that rationalisations during the 1990s had led to a low prioritising of performing checks and of small repairs in the three Fambo estates. These characteristics were concluded theoretically to result in as much as 28% lower and less varying water use in the HSB estate than in the Fambo estates. (Brunklaus, 2009a, p. 131.)

Regarding washing machines, water supply pipes, and draining system, it was reported that potentially environmentally significant differences were found in replacement of the equipment, in knowledge about the systems, and in operation and maintenance. It was presented that washing machines, water supply pipes and draining systems had been replaced throughout the 1970s and 1980s in the HSB estate, and that they were going to be replaced through the next renovation in the Fambo estates. Further, it was reported that rationalisations during the 1990s had led to a low prioritising of performing checks and of repairs in the Fambo estates. These characteristics were concluded theoretically to result in as much as 19% lower and less frequently varying water use in the HSB estate than in the Fambo estates. (Brunklaus, 2009a, p. 131.)

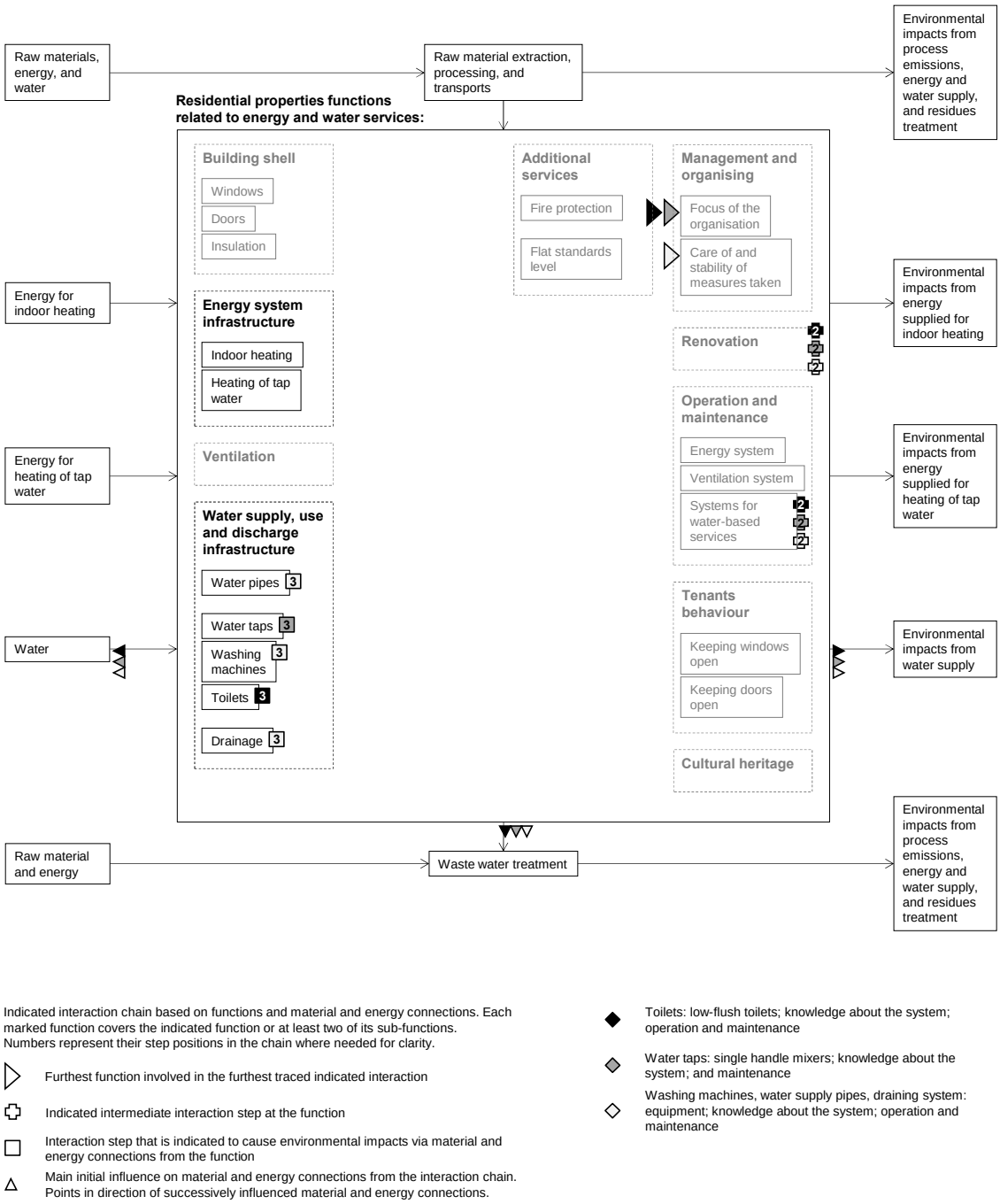
It was concluded that all these differences in the water-based services and their management could explain from water use reports extracted figures on water use levels (Brunklaus, 2009a, p. 129). It was reported that the HSB estate according to these figures during 1996–2002 used around 50% less water on average than and experienced less variations in water use than the Fambo estates used and experienced during 1993–2002 (Brunklaus, 2009a, p. 124). Regarding these differences, it was reported that they had been traced to the same management aspects as for the energy comparisons in (A) above. It was presented that the water use averages reported on were found to result from the effects of a management that was adopted to building characteristics at

the HSB estate, and of time constraints and a focus on tenant demands at Fambo. It was presented that the water use variations reported on were found to result from a caring and stable organisation of operation being deployed at the HSB estate and from a use of an emergency-driven approach at Fambo. (Brunklaus, 2009a, p. 129.)

See Table 8.4 and Figure 8.4, further on in this sub-chapter, for summaries of the described reported on types of water-based services characteristics and management at the HSB and Fambo estates and the indicated environmental significance of these conditions.

Table 8.4: Reported water-based services and their management in the HSB estate and the Fambo estates resulting in differences in environmental performance (C) (adapted with minor modifications from Brunklaus, 2009a, p. 131)

	HSB	Fambo
Toilets: differences regarding low-flush toilets, knowledge about the systems, and operation and maintenance reported theoretically to lead to as much as 12% higher but less varying water use in the HSB estate than in the Fambo estates	It was reported that low-flush toilets were not installed through renovation. It was reported that the knowledge of the system and of its water use was good, and that maintenance was performed when needed.	It was reported that low-flush toilets had been installed in parts of the estates after emergencies. It was reported that there was, due to rationalisations during the 1990s, only little prioritising of performing checks and of small repairs.
Water taps: differences regarding single handle mixers, knowledge about the systems, and operation and maintenance reported to theoretically lead to as much as 28% lower and less varying water use in the HSB estate than in the Fambo estates	It was reported that single handle mixers were installed through renovation in the 1980s. It was reported that the knowledge of the system and of its water consumption was good, and that maintenance was performed when needed.	It was reported that single handle mixers had been installed in parts of the estates after emergencies. It was reported that there was, due to rationalisations during the 1990s, only little prioritising of performing checks and of small repairs.
Washing machines, water supply pipes, and draining systems: differences regarding replacement of the equipment, knowledge about the systems, and operation and maintenance reported to theoretically lead to as much as 19% lower and less varying water use in the HSB estate than in the Fambo estates	It was reported that washing machines, water supply pipes, and draining system were replaced throughout the 1970s and 1980s.	It was reported that washing machines, water supply pipes, and draining system were going to be replaced during the next renovation. It was reported that there was, due to rationalisations during the 1990s, only little prioritising of performing checks and of repairs.
➔ Taken together, these differences were concluded to account for the on average as much as 50% lower and less varying water use figures presented for the HSB estate during 1996–2002 than for the Fambo estates during 1993–2002. Regarding these differences, it was reported that they had been traced to the same management aspects as for the energy comparisons in (A) above. It was presented that the water use averages reported on were found to result from the effects of a management that was adopted to building characteristics at the HSB estate, and of time constraints and a focus on tenant demands at Fambo. It was presented that the water use variations reported on were found to result from a caring and stable organisation of operation being deployed at the HSB estate and from a use of an emergency-driven approach at Fambo.		



Indicated interaction chain based on functions and material and energy connections. Each marked function covers the indicated function or at least two of its sub-functions. Numbers represent their step positions in the chain where needed for clarity.

- Furthest function involved in the furthest traced indicated interaction
- Indicated intermediate interaction step at the function
- Interaction step that is indicated to cause environmental impacts via material and energy connections from the function
- Main initial influence on material and energy connections from the interaction chain. Points in direction of successively influenced material and energy connections.
- Toilets: low-flush toilets; knowledge about the system; operation and maintenance
- Water taps: single handle mixers; knowledge about the system; and maintenance
- Washing machines, water supply pipes, draining system: equipment; knowledge about the system; operation and maintenance

Figure 8.4: Main interaction paths connected to the reported on management with indicated significant influence on product life cycle environmental performance of water-based services in the HSB and Fambo estates

8.7. Water-based services and their management, according to account II on Dalavik and Wallenstam (D)

The reported theoretical differences in environmental impacts between the Dalavik and Wallenstam estates regarding water-based services and the organisational practices connected to them, are in this sub-chapter presented.

Regarding toilets, it was reported that potentially environmentally significant differences were found regarding year of replacement. It was described that the toilets had been replaced in 1994 in the Dalavik estate, and in 1975 at Wallenstam. These characteristics were concluded theoretically to result in as much as 12% less water use in the Dalavik estate than in the Wallenstam estates. (Brunklaus, 2008, Paper III, p. 12.)

Regarding water taps, it was reported that potentially environmentally significant differences were found in the use of mixers. It was described that the mixers were from 1994 in the Dalavik estate and from 1975 at Wallenstam. These characteristics were concluded theoretically to result in as much as 28% less water use in the Dalavik estate than in the Wallenstam estates. (Brunklaus, 2008, Paper III, p. 12.)

Regarding water supply pipes, it was reported that potentially environmentally significant differences were found in the year of replacement. It was described that the pipes were replaced in 1994 in the Dalavik estate, and in 1975 at Wallenstam. These characteristics were concluded theoretically to result in less varying water use in the Dalavik estate than in the Wallenstam estates. (Brunklaus, 2008, Paper III, p. 12.)

It was concluded that all these differences in the water-based services and their management could not fully explain from water use reports extracted figures on water use differences between these estates. It was presented that the water use averages reported on were found to show a small gradual decrease during 1994–2005 in the Dalavik estate, and a rapid increase during 1999–2005 in one of the Wallenstam estates. It was presented that these differences maybe were caused by Wallenstam not having performed enough data collection, and that Dalavik possibly had improved their operation of the water-based services and that they themselves had found that this change in operation had occurred. (Brunklaus, 2008, Paper III, pp. 6, 12–13.)

See Table 8.5 and Figure 8.5, further on in this sub-chapter, for summaries of the described reported on types of water-based services characteristics and management at the Dalavik and Wallenstam estates and the indicated environmental significance of these conditions.

Table 8.5: Reported water-based services and their management in the Dalavik estate and one of the Wallenstam estates resulting in differences in environmental performance (D) (adapted with minor modifications from Brunklaus, 2008, Paper III, p. 12)

	Dalavik	Wallenstam
Toilets: differences regarding replacement year reported to theoretically lead to as much as 12% lower water use in the Dalavik estate than in the Wallenstam estate	It was reported that they were replaced in 1994.	It was reported that they were replaced in 1975.
Water taps: differences regarding mixers reported to theoretically lead to as much as 28% lower water use in the Dalavik estate than in the Wallenstam estate	The mixers were reported to be from 1994.	The mixers were reported to be from 1975.
Water supply pipes: differences regarding replacement year reported to theoretically lead to less varying water use in the Dalavik estate than in the Wallenstam estate	It was reported that they were replaced in 1994.	It was reported that they were replaced in 1975.
➔ Taken together, these differences were concluded not to fully account for the differences in the water use figures presented on the Dalavik estate for 1994–2005 and on the Wallenstam estate for 1999–2005. It was presented that the water use averages reported on were found to show a small gradual decrease during 1994–2005 in the Dalavik estate, and a rapid increase during 1999–2005 in one of the Wallenstam estates. It was presented that these differences maybe were caused by Wallenstam not having performed enough data collection, and that Dalavik possibly had improved their operation of the water-based services and that they themselves had found that this change in operation had occurred.		

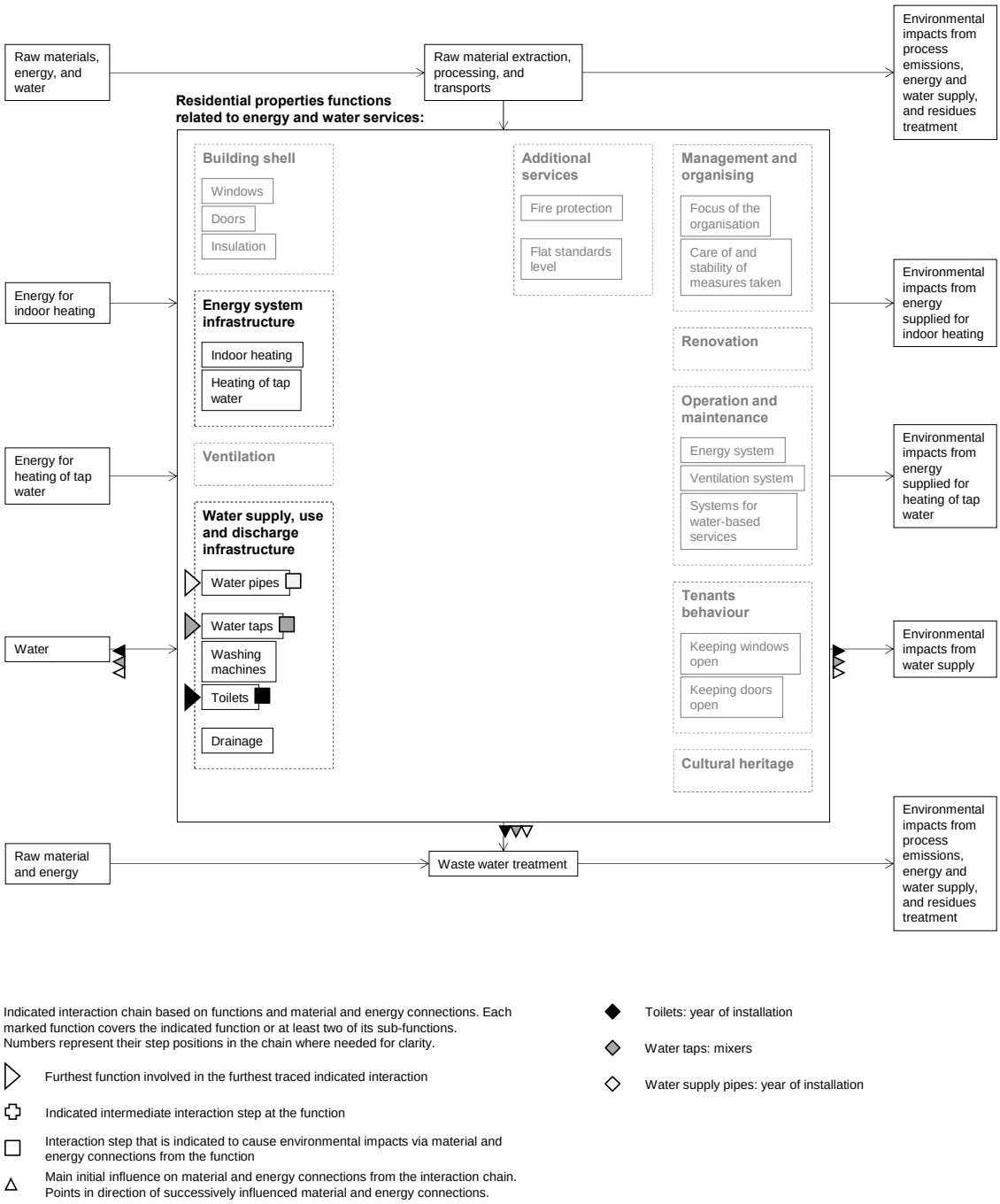


Figure 8.5: Main interaction paths connected to the reported on management with indicated significant influence on product life cycle environmental performance of water-based services in the Dalavik and Wallenstam estates

8.8 Analysis and summary of the test case

In this sub-chapter, we present a combination of the outcome of an analysis of and a summary of the previously in this chapter presented findings. These findings cover for the HSB and Fambo studies six and for the Dalavik and Wallenstam studies six groups of properties management practices and their indicated potentially significant influence the product life cycle environmental

impacts. These environmental impacts were indicated to be moderate to large from the perspective of environmentally harmful emission and resource use occurring in Northern Europe.

The properties management test case differs from the other five test cases in four main ways. It was carried out using fully to the study objects specific quantitative data of the material and energy uses covered, and it was based on already published studies. Further, these publications precedes this project and were reported to be performed as pilot studies for the method, and, finally, the test case covered two studies that each contained a similar coverage of energy-based services and water-based services and to them seemingly connected practices and environmentally impacting materials and energy use.

Further, the degree of certainty of environmental significance of these twelve groups of practices have been found to lie around high besides for a moderate degree for the water-based services of Dalavik and Wallenstam. This conclusion is founded in that it is reported that the studies were based on many visits, many interviews and many documents internal to the studied organisations, and that it is reported that the practices besides the Dalavik and Wallenstam water-based services showed close correspondence between theoretical effects of different appliances and the presented water and energy use figures.

Further, each of the six groups of practices reported on for the HSB and Fambo estates seems to be connected to each of the other of these groups of practices in rather well understood ways and mainly moderately but for a smaller share of the connections strongly. These connections have been found to particularly go via renovation practices, Fambo's emergency oriented approaches, Fambo rationalisations leading to little prioritising on energy and water issues, and Fambo focus on flat standards. This is outlined for the respective connections in Table 8.6, further on in this sub-chapter. Further, these six groups of practices seem to include coverage of six seemingly generic issues that might to be of environmental relevance for many other activities in society and which seem to cover the main findings for all of these practices. These six are handling of seemingly conflicting aspects, rationalisation, co-ordination of measures of which some affect environmentally impacting devices, cyclic, continuous, emergency-driven, or needs adjusted actions, client demands contrary to following demands of the material and energy systems, and knowledge of technical systems and of their performances. The taken together seeming importance of each of these except handling of seemingly conflicting aspects for understanding each of these six groups of practices is very high for a majority share, none or low for a considerable share, and high for a small share. This is outlined per issue and per group of practices in Table 8.7, further on in this sub-chapter.

Table 8.6: Indicated strengths of connections between the covered properties management practices at HSB and Fambo in account I

Indicated environmentally significant practice. A: Energy-based services C: Water-based services	Strength of connection between the practice and the other practices. 0 = no or very weak, 1 = weak, 2 = moderate, 3 = strong					
	A.1	A.2	A.3	C.1	C.2	C.3
A.1–A.3 & C.1–C.3 It was presented that the energy and water use averages reported on were found to result from the effects of a management that was adopted to building characteristics at the HSB estate, and of time constraints and a focus on tenant demands at Fambo. It was presented that the energy and water use variations reported on were found to result from a caring and stable organisation of operation being deployed at the HSB estate and from a use of an emergency-driven approach at Fambo.						
A.1 Types of windows related to cultural heritage: Double or triple glazed windows installation in relation to cultural heritage demands reported to theoretically lead to 5–10% lower energy use in the HSB estate than in the Fambo estates		2	2	2	2	2
A.2 Insulation, mechanical ventilation, and energy systems in relation to renovation differences: It was reported theoretically to lead to 5–10%, 10–15%, and 10–15% lower energy use, respectively, in the HSB estate than in the Fambo estates. For the HSB estate, it was reported that energy demands in renovation had resulted in adding of attic insulation and mechanical ventilation, and installation of a heat recovery system and a heat pump. For the Fambo estates, it was reported that renovations were performed on a cyclic basis, and that energy use levels were in focus during Fambo renovations in the 1970s but not when these properties were renovated in the 1980s. It was also reported that Fambo rationalisations in the 1990s led to considering energy requirements as too time consuming to focus on at the same time as increased flat standards levels became prioritised.			2	2	3	2
A.3 Operation practise differences for energy system and ventilation: Reported theoretically to lead to less variation in energy use in the HSB estate than in the Fambo estates. For the HSB estate, it was reported that checks and adjustments were made continuously. For the Fambo estates, it was reported that Fambo rationalisations in the 1990s led to using a pre-defined schedule for monitoring the properties, and that actions were only carried out were energy consumption had risen to critical levels.				2	2	2
C.1 Toilet and renovation and emergencies, system knowledge and operation and maintenance differences: Reported theoretically to lead to as much as 12% higher but less varying water use in the HSB estate than in the Fambo estates. It was reported that for the HSB estate, the knowledge of the system and of its water use was good, and that maintenance was performed when needed. It was reported for the Fambo estates that low-flush toilets had been installed in parts of the estates after emergencies, and that due to rationalisations during the 1990s there was only little prioritising of performing checks and of small repairs.					3	2
C.2 Water taps and renovation and emergencies, system knowledge and operation and maintenance differences: Reported theoretically to lead to as much as 28% lower and less varying water use in the HSB estate than in the Fambo estates. It was reported that for the HSB estate single handle mixers were installed through renovation in the 1980s, that the knowledge of the system and of its water consumption was good, and that maintenance was performed when needed. It was reported for the Fambo estates that single handle mixers had been installed in parts of the estates after emergencies, and that there due to rationalisations during the 1990s was only little prioritising of performing checks and of small repairs.						2
C.3 Washing machines, pipes, and drainage replacement differences, system knowledge level, and operation and maintenance differences: It was reported to theoretically lead to as much as 19% lower and less varying water use in the HSB estate than in the Fambo estates. For the HSB estate, it was reported that washing machines, water supply pipes, and draining system were replaced throughout the 1970s and 1980s. For the Fambo estates, it was reported that washing machines, water supply pipes, and draining system were going to be replaced during the next renovation, and that there due to rationalisations during the 1990s was only little prioritising of performing checks and of repairs.						

Table 8.7: Seeming generic issues and their indicated importance for explaining the covered properties management practices at HSB and Fambo in account I

Seeming generic issues	Indicated importance for explaining the practices. 0 = no or low, 1 = moderate, 2 = high, 3 = very high					
	A. 1	A. 2	A. 3	C. 1	C. 2	C. 3
Handling of seemingly conflicting aspects	3	0	0	0	0	0
Rationalisation	0	3	3	3	3	3
Co-ordination of measures of which some affect environmentally impacting devices	3	3	0	0	3	3
Cyclic, continuous, emergency-driven, or needs adjusted actions	0	3	3	3	3	3
Client demands contrary to following demands of the material and energy systems	3	3	3	3	3	3
Knowledge of technical systems and of their performances	3	2	2	3	3	2

Further, most of the six groups of practices reported on for the Dalavik and Wallenstam estates seems to be connected to each of the other of these groups of practices in ways that are likely rather easily discernible and mainly moderately or weakly but for a considerable share not or very weakly. These connections have been found particularly to go via installation years of different energy and water systems, and ventilation and temperature aspects. This is outlined for the respective connections in Table 8.8, further on in this sub-chapter. Further, these six groups of practices seem to include coverage of four seemingly generic issues that might to be of environmental relevance for many other activities in society and which seem to cover the main findings for all of these practices. These six are users' actions, side effects of measures performed for other reasons than adjusting the environmentally impacting properties of material and energy systems, year of installation, and year of replacement. The taken together seeming importance of these for understanding each of these six groups of practices is very high to a majority degree, and none or low to a considerable degree. This is outlined per issue and per group of practices in Table 8.9, further on in this sub-chapter.

Table 8.8: Indicated strengths of connections between the covered properties management practices at Dalavik and Wallenstam in account II

Indicated environmentally significant practice. B: Energy-based services D: Water-based services	Strength of connection between the practice and the other practices. 0 = no or very weak, 1 = weak, 2 = moderate, 3 = strong					
	B.1	B.2	B.3	D.1	D.2	D.3
B.1–B.3 & D.1–D.3 It was presented that the energy use averages reported on were found to result from the effects of a management based on a professional type of organising that was adapted to buildings at the Wallenstam estates, and of a self-made management style and economic constraints conflicting with tenant demands at Dalavik. Further, it was reported that the water use averages reported on could not fully be explained by management. It was presented that these averages were found to show a small gradual decrease during 1994–2005 in the Dalavik estate, and a rapid increase during 1999–2005 in one of the Wallenstam estates. It was presented that these differences maybe were caused by Wallenstam not having performed enough data collection, and that Dalavik possibly had improved their operation of the water-based services and that they themselves had found that this change in operation had occurred.						
B.1 Windows and doors kept open degrees: To which degree tenants keep windows and doors open reported theoretically to lead to 5% less energy use in the Wallenstam estates than in the Dalavik estate. It was reported that these were kept open to a higher degree at the Dalavik estate than at the Wallenstam estates.		1	1	0	0	0
B.2 Insulation difference and fire protection: Reported theoretically to lead to as much as 30% less energy use in the Wallenstam estates than in the Dalavik estate. It was reported that no insulation was added at the Dalavik estate and that due to fire concerns internal insulation was added in 1975 in the Wallenstam estates.			2	2	2	2
B.3 Ventilation installation difference: Year of installation reported theoretically to lead to as much as 5% lower energy use in the Dalavik estate than in the Wallenstam estates. It was reported that it was installed in 1992 in the Dalavik estate and in 1975 in the Wallenstam estates.				1	1	1
D.1 Toilets replacement difference: Replacement year of toilets reported theoretically to lead to as much as 12% lower water use in the Dalavik estate than in the covered Wallenstam estate. It was reported that they were replaced in 1994 in the Dalavik estate and in 1975 in the Wallenstam estate.					2	2
D.2 Mixers replacement difference: Water tap mixers difference reported theoretically to lead to as much as 28% lower water use in the Dalavik estate than in the covered Wallenstam estate. It was reported that they were from 1994 in the Dalavik estate and from 1975 in the Wallenstam estate.						2
D.3 Pipes replacement difference: Replacement year of water supply pipes reported theoretically to lead to less varying water use in the Dalavik estate than in the covered Wallenstam estate. It was reported that they were replaced in 1994 in the Dalavik estate and in 1975 in the Wallenstam estate.						

Table 8.9: Seeming generic issues and their indicated importance for explaining the covered properties management practices at Dalavik and Wallenstam in account II

Seeming generic issues	Indicated importance for explaining the practices. 0 = no or low, 1 = moderate, 2 = high, 3 = very high					
	B. 1	B. 2	B. 3	D. 1	D. 2	D. 3
Users' actions	3	0	0	0	0	0
Side effects of measures performed for other reasons than adjusting the environmentally impacting properties of material and energy systems	0	3	0	0	0	0
Year of installation	0	0	3	3	3	3
Year of replacement	0	0	0	3	3	3

Further, it seems at least for each of the nine groups of practices in A-C rather clear whether and to which degree they in a certain state lead to increased, decreased, or similar product life cycle environmental impacts. The publications that the properties management test case uses seems to convincingly show how an approach of adding these effects of individual groups of practices results in an explanation of overall from quantitative records extracted differences between the different studied estates for three of the four comparisons made.

The here reported on and analysed publications also seem to show that an organisational understanding was necessary for explaining all of the covered differences in technology that influenced energy and water were use. In addition, variations in energy and water use have been highlighted as potentially environmentally relevant in addition to average use levels.

Taken together, this test case can be exemplified through the following practices and their influences on environmental performance:

- Types of windows related to the handling of cultural heritage requirements in the HSB and Fambo account, and its environmental impact through influencing the need of indoor heating and thus among other emissions from heating supply

- Water taps replacement related to renovation and emergencies, system knowledge and operation and maintenance differences in the HSB and Fambo account, and their environmental impacts through influencing amounts and variations in water use and thus environmental impacts caused among other via water purification of the supplied water

- Insulation differences due to fire protection differences in the Dalavik and Wallenstam account, and its environmental impact through influencing the need of indoor heating and thus among other emissions from heating supply

Further, these and other of the identified practices were presented as in straightforward ways being related to each other through a few different overarching management approaches.

Thus, taken together, the properties management test case shows how a thorough nodal LCA organisation study was reported to have resulted in a number of overarching findings. These are listed in table 8.10, further on in this sub-chapter.

Table 8.10: Overview of findings on the usefulness of the through reports covered thorough nodal LCA organisation study on properties management with properties as nodes

Practices were reported as explaining overall from quantitative records extracted differences in energy and water use levels and variations in three out of four cases
These practices were presented as in straightforward ways being related to each other through a few different overarching management approaches
An organisational understanding was necessary for explaining all of the covered differences in technology that influenced energy and water were use

9. ROAD MANAGEMENT (BASED ON TEST CASE 6)

In this chapter, we focus on the in the road management test case identified organisational practices of indicated product life cycle environmental significance for the service operation and routine maintenance of roads and traced from nodal sites of three geographical areas used as units for procurement and performance of these activities in the larger Gothenburg region, Sweden. These road management activities cover for example power supply to road lights and measures to handle snow and ice, and their delimitation closely corresponds to the activities labelled as operation of roads in an LCA of roads by Stripple (2001) (cf. Trafikverket, 2010d).

The construction, maintenance, and operation of roads seems to have been targeted only little from an environmental perspective since they have been considered to be significantly less environmentally impacting than the actual traffic on roads (cf. Stripple, 2001, p. II). However, a pilot study on these road activities presented for example energy use for these activities from an LCA perspective was presented as amounting to around 5–12% of the energy use of the road traffic on a road with a traffic density of 5000 vehicles/day. The corresponding energy use for road operation and routine maintenance was presented to amount to around 5% of the energy use of the road traffic on roads with road lighting and traffic lights, and to around 0.3% on roads without road lighting and traffic lights. (Stripple, 2001, p. 87–89, Appendix Road Model)

9.1. Study objects

9.1.1. Selection of study objects

Three geographical areas in the larger Gothenburg region that were used as units for procurement and performance of operation and routine maintenance of roads, were selected as nodal sites in the road management test case. This road management does not include urban streets (cf. Trafikverket, 2010a, b, c). Initially, the test case was designed to compare the road operation of three similar stretches of highways that all originated in the central areas of Gothenburg. Based on the actual division of operation areas, however, the three mentioned areas were studied via the project managers of the procurement of the road operation and routine maintenance in these areas at the Swedish Transport Administration (Trafikverket). The functional unit that the test case is based on is *operation and routine maintenance of one km of road*.

9.1.2. Data collection

The road management test case is based on one interview with the project managers for the mentioned procurement of the three geographical areas for operation and routine maintenance of

roads at the Swedish Transport Administration, as well as on material from the website of the Swedish Transport Administration and of research publications on road management.

9.1.3. About the three sub-cases

The procurement areas covered in the road management test case focussed on Gothenburg (in Swedish 'driftområde Göteborg'), Kungsbacka (in Swedish 'driftområde Kungsbacka'), and Kungälv/Tjörn (in Swedish 'driftområde Kungälv/Tjörn'), respectively. As of 21 December 2010, the procurement for the former two of these was managed by project manager Roy Barresten and the procurement for the latter one by project manager Morgan Wester. (Barresten and Wester, per. comm. 2010.)

The operation and routine maintenance of public Swedish roads except urban streets was at the time of the study performed through procurement. Previously, this road operation and routine maintenance was performed by a state owned organisation, and the procurement-based system was gradually introduced between 1992 and 2001. (Barresten and Wester, per. comm. 2010; Liljegren, 2003.) The national agency the Swedish Transport Administration procured the operation on six-year contracts at the time of this study (Barresten and Wester, per. comm. 2010).

An overview of the basic characteristics of the three in the road management test case covered procurement units is presented in Table 9.1, further on in this sub-sub-chapter.

Table 9.1: Overview of general characteristics of three units for procurement of operation and routine maintenance of public roads except urban streets (as of 31 August 2010 for Gothenburg and Kungälv/Tjörn, and 1 Sept. 2010 for Kungsbacka) (Sources: Trafikverket, 2010a, b, c)

	Gothenburg	Kungsbacka	Kungälv/Tjörn
Road length that was covered in the area of the unit	253	436	788
Geographical area covered	Closely corresponding to the area of Gothenburg municipality that was located to the west of the E6 road.	Closely corresponding to the area of Kungsbacka municipality plus the E6 road south of the town centre of Mölndal.	Closely corresponding to the area of the municipalities Ale, Kungälv, Stenungsund, and Tjörn.
Holder of procurement contract at the time of the study	Svevia	Peab	Peab

9.2. Life cycle assessment review

The environmentally impacting activities considered in the road management test case correspond closely to the ones presented in the previously mentioned LCA by Stripple (2001). The routine maintenance covered does not include, for example, repaving and bridge and tunnel maintenance. Further, the operation and routine maintenance of the road lights in the roads covered through procurement in Sweden was at the time of this study to an increasing extent not being part of these units of procurement. (Barresten and Wester, per. comm. 2010.)

The from an LCA perspective environmentally impacting operation and routine maintenance road activities here covered are outlined in Figure 9.1, further on in this sub-chapter.

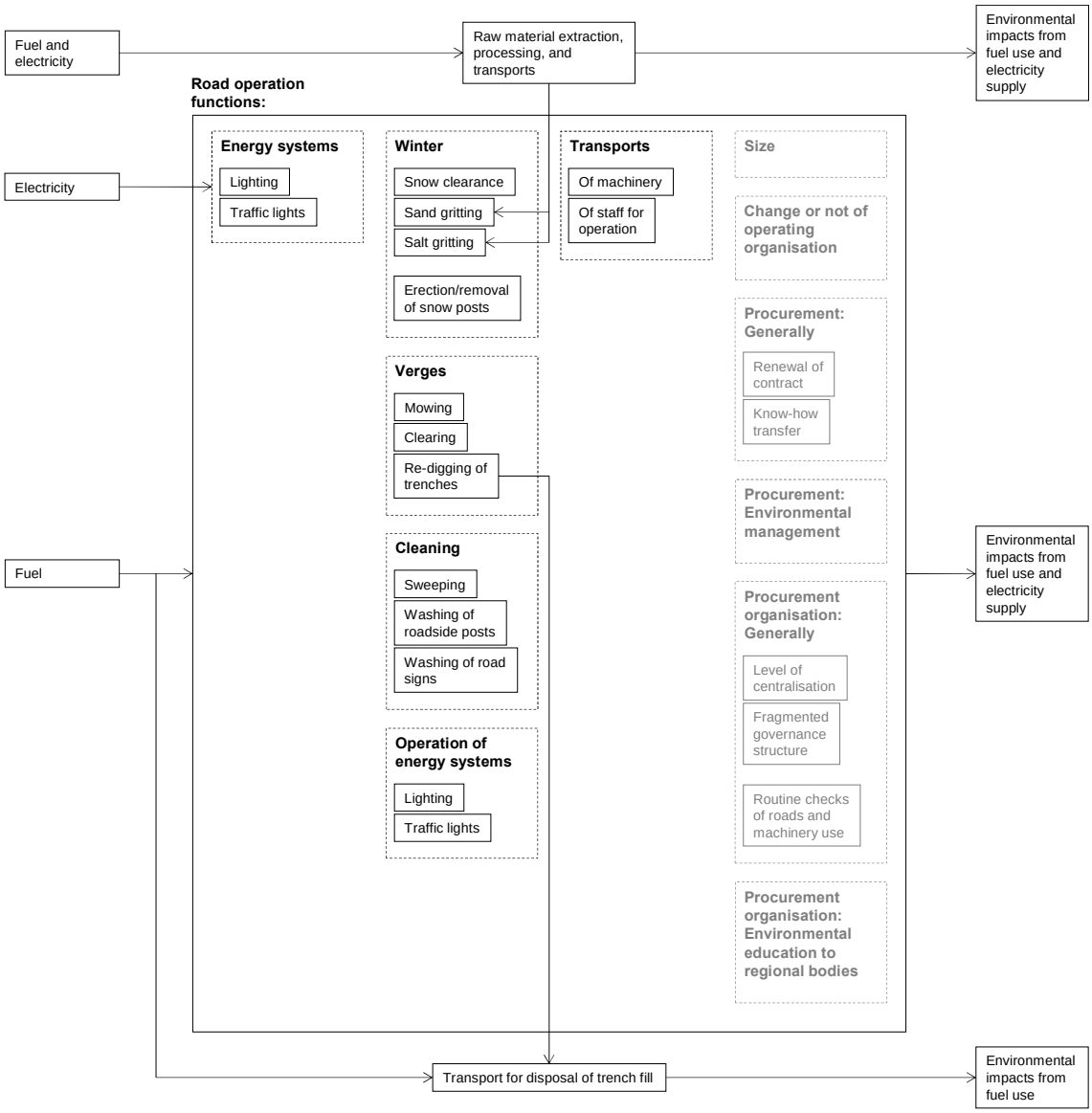


Figure 9.1: Overview of reviewed indicated product life cycle environmentally significant functions for the three units of road management procurement. Directly through material and energy connections environmentally contributing functions in black, and

indirectly contributing ones in grey (adapted with minor modifications from parts of Stripple, 2001, pp. 18–20).

9.3. Socio-material points of interaction at the product life cycles

The socio-material interactions at the product life cycles via which organisational practices have been indicated to cause considerable environmental consequences in the road management test case are connected to procurement related management by the procurement contract holders (A), and to the management of the procurement performed by the regional and national bodies of the Swedish Transport Administration (B).

9.4. Procurement related management by the procurement contract holders (A)

In relation to the use of procurement of operation and routine maintenance of roads and at the same time mainly being located at the organisations holding the procurement contracts, two potentially environmentally significant organisational practices were identified in the road management test case. Through a publication on a study on road maintenance contracts in Sweden it was found that a change of one contractor at the end of a procurement period was followed by no significant increase in fulfilling environmental requirements while a corresponding change of contractor coincided with an increased fulfilment rate (Faith-Ell et al., 2006, p. 166). This points out that the contract transfer and renewal is a potentially environmentally relevant process. In line with this, a lack of transfer of knowhow when a change of contractor occurs in procurement was presented to be one general issue of the operation and routine maintenance of roads in Sweden at the time of the study. It was said that the contractors found it in practice difficult to transfer their routines and other knowledge of the road operation and routine maintenance activities effectively. In addition, from a competition point of view, they were said to be unwilling to provide this knowhow to their successors since an unsuccessfully competing contractor might make it easier to win the procurement of that unit six years later. (Barresten and Wester, per. comm. 2010.) As a possible result, ineffective planning of the operation of and use of machinery might lead to increased environmental impacts that could explain the in the other study reported difference in fulfilment of environmental requirements.

The other in the road management test case identified potentially environmentally significant organisational practice regarding contractor aspects on procurement is a strategic striving for contractors to perform the road operation and routine maintenance simultaneously of several geographically adjacent units. This was in the test case pointed out for the larger Gothenburg area, where one unit was located in the city of Gothenburg and acted as a natural hub for the units

located adjacent to it, in the less central areas of the Gothenburg metropolitan region. Thus, the contractors were said to seek control of the Gothenburg unit in combination with at least some of the surrounding units. If this was achieved, Gothenburg could be used as a hub for the contractor's activities and management. (Barresten and Wester, per. comm. 2010.) Such a centralisation could potentially lead to for example more transports of machinery and staff and thereby lead to increased environmental impacts.

See Table 9.2 and Figure 9.2, further on in this sub-chapter, for summaries of the described types of procurement related management by the procurement contract holders and their indicated environmental significance.

Table 9.2: Procurement related management by the procurement contract holders (A)

	Change that was said to have occurred
Procurement: Fulfilment of environmental requirements indicated to increase after renewal of procurement contract to the same contractor. Switching to a new contractor has on the other hand been indicated not to lead to increased fulfilment of environmental requirements and to lack of transfer of experience and thereby potentially less well-planned and more environmentally impacting activities.	Procurement had replaced owning by the state of road operation and routine maintenance in Sweden, between 1992 and 2001.
Centralisation of contractors' activities and their management may lead to increased environmental impacts from for example transportation of machinery and staff for road operation and routine maintenance.	Contractors have strived, at least in the Gothenburg metropolitan area, simultaneously to control a centrally located procurement unit and at least some of the surrounding units.
➔ A more detailed study of the occurrence of switching contractors at the end of procurement periods, the contractors' environmental performance, and the potential centralisation of facilities for operational and managerial contractor activities may reveal environmental impacts differences between the three studied procurement units.	

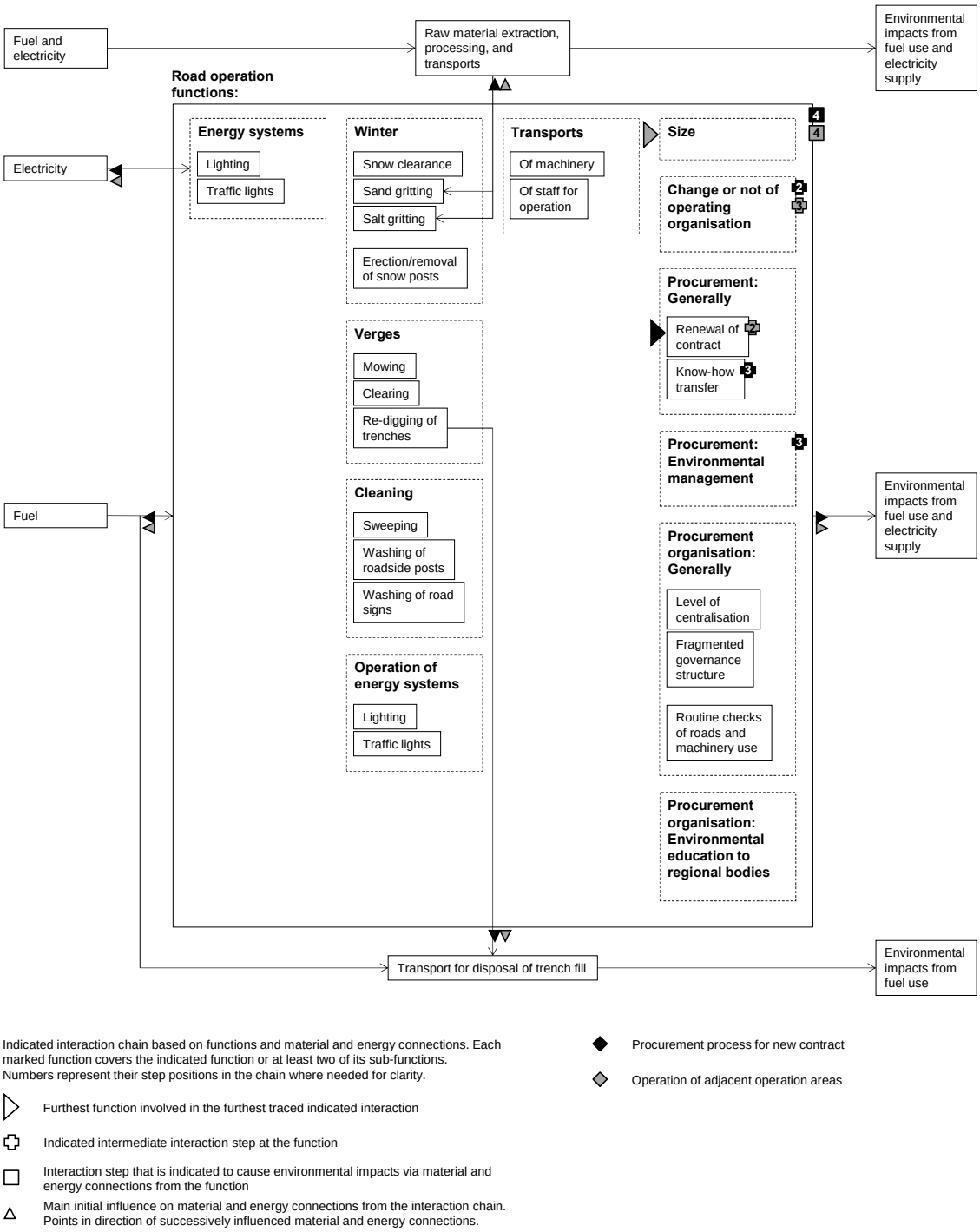


Figure 9.2: Main covered interaction paths connected to the procurement related management by the procurement contract holders that is indicated to influence product life cycle environmental performance

9.5. Management by procuring organisations (B)

Regarding the management of the organisations procuring the Swedish road operation and routine maintenance, two organisational practices of potential environmental significance were identified in the road management test case. First, at the time of the study, it was said that the procurement

organisations' relation to the contractors was becoming increasingly fragmented. Different aspects of the road operation and routine maintenance was said to be governed by an increasing number of different parts of the Swedish Transport Administration, despite that a large share of these different activities often were the performed by the same contractor. (Barresten and Wester, per. comm. 2010.) Such fragmentation might lead to less effective work on the environmental aspects, due to the overarching characteristics of many of these.

Second, an increasingly centralised organising of the Swedish Transport Administration was found to be of potential environmental significance through the road management test case. At the time of the study, it was highlighted that the Swedish Transport Administration had become increasingly centrally governed compared to an earlier large degree of self-governing at the regional level of the agency (Barresten and Wester, per. comm. 2010, p. 4). In relation to this, a publication on a general study of the introduction of market driven procurement of Swedish road operation and maintenance pointed out that this market driven procurement was introduced in a de-centralised organisation. The regionalised state of the organisation at the time of the introduction of market driven procurement was stated to have been both assisting and preventing the organisational learning capacity. It was presented to assist in this through a high degree of regional freedom and a motivation from challenges faced, and prevent it through a low level of sharing between the regions of the agency. (Liljegren, 2003.) This organising related to learning aspects may be of environmental relevance due to among other the often abstract and overarching characteristics of environmental aspects.

See Table 9.3 and Figure 9.3, further on in sub-chapter, for summaries of the here covered management by procuring organisations, and its indicated environmental significance.

Table 9.3: Management by procuring organisations (B)

	Change that was said to have occurred
Fragmentation of the governance by procurement organisations may lead to less environmentally effective handling of the overarching characteristics of many environmental aspects.	At the time of this study, an increasing number of different parts of the Swedish Transport Administration governed the operation and routine maintenance of roads, despite that many of these activities often were performed by the same contractor.
De-centralisation has been reported to assist organisational learning capacity through freedom and the motivation form challenges faced, and to prevent this learning capacity through little sharing between the regions of the agency. This organising related to learning aspects may be of environmental relevance due to among other the often abstract and overarching characteristics of environmental aspects.	At the time of the study, the procuring agency had changed from a strongly de-centralised organisation to a centralised one.
➔ A more detailed study of the environmental effects of different fragmentation degrees in the governance by the procuring organisations, the organisational learning on environmental aspects at different degrees of organisational centralisation, and the relation between organisational knowledge on environmental aspects and environmental performance may reveal environmental impacts differences between different organising practices at the studied procurement agency.	

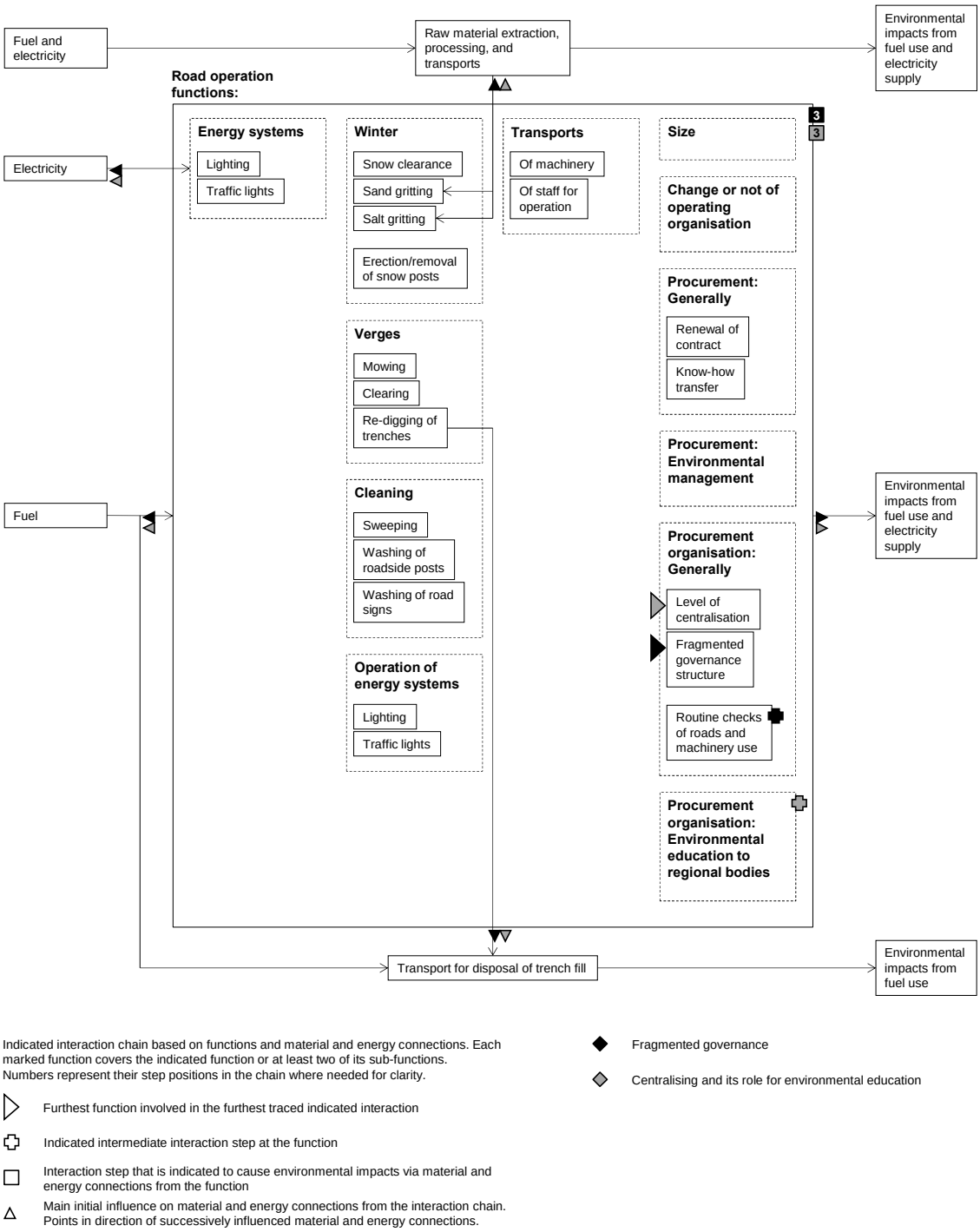


Figure 9.3: Main covered interaction paths connected to the management by procuring organisations that is indicated to influence product life cycle environmental performance

9.6. Analysis and summary of the test case

In this sub-chapter, we present a combination of the outcome of an analysis of and a summary of the previously in this chapter presented four road operation and routine maintenance practices and their indicated potentially significant influence the product life cycle environmental impacts.

These environmental impacts were indicated to be moderate from the perspective of environmentally harmful emission and resource use occurring in Sweden. The degree of certainty of environmental significance of these practices have been found to lie between moderate and low. This is due to that the test case mainly is based on a combined interview with actors not directly involved in the road operation and routine maintenance activities as such and on proxy indicators for environmental performance combined with results presented in a report on a road LCA. Further, each of the four practices seems to be connected to each of the other practices in not necessarily discernible ways, mainly weakly but for a considerable share moderately, and these connections seemingly occurred mainly via the issue of whether procurement was used or not. This is outlined for the respective connections in Table 9.4, further on in this sub-chapter. In addition, the practices were found to be dependent on the service characteristic of at the time of the study being carried out by market actors while being procured by a national agency. Further, the practices seem to include coverage of five seemingly generic issues that might to be of environmental relevance for many other activities in society and which seem to cover the main findings for all of the four practices identified. The taken together seeming importance of these for understanding each of the four practices is none or low, moderate, or very high to considerable degrees. This is outlined per issue and per practice in Table 9.5, further on in this sub-chapter.

Table 9.4: Indicated strengths of connections between the covered road operation and routine maintenance practices

Indicated environmentally significant practice. A: Management by the procurement contract holders B: Management by procuring organisations	Strength of connection between the practice and the other practices. 0 = no or very weak, 1 = weak, 2 = moderate, 3 = strong			
	A.1	A.2	B.1	B.2
A.1 *Renewal or not of procurement contracts: Whether procurement contracts are renewed for the same contractor and its influence on fulfilment of environmental requirements and transfer of general knowhow		2	1	1
A.2 *Centralisation of contractors activities			1	1
B.1 *Fragmentation of procurement governance: Often affecting the same contractor and having an influence on environmental effectiveness through among other the overarching characteristics of many environmental aspects				2
B.2 Centralisation degree of procuring agency: Its stated likely influence on organisational learning on environmental aspects from flexibility, motivating challenge, and exchange of knowledge on the overarching characteristics of many environmental aspects				

Table 9.5: Seeming generic issues and their indicated importance for explaining the covered road operation and routine maintenance practices

Seeming generic issues	Indicated importance for explaining the practices. 0 = no or low, 1 = moderate, 2 = high, 3 = very high			
	A.1	A.2	B.1	B.2
The effect of using or not using procurement	3	3	0	0
Organisational discontinuity	3	1	0	0
Increased transports from centralising	1	3	0	0
Organisational fragmentation	1	0	3	1
Centralisation and learning about environmental aspects	0	0	1	3

Further, it seems for the four practices not clear whether each of them in a certain state would lead to increased, decreased, or similar product life cycle environmental impacts. Related to this, the road management test case was performed in a way that did not facilitate a direct ranking or other comparison between the three procurement units, but rather regarding different general changes said to have occurred over time.

Nevertheless, the presentation based on the screening seems to show that the environmental performance is not easily deduced from the material and energy input to the road operation and routine maintenance and the number of kilometres handled, as would be the procedure in standard LCA. Even if no direct quantitative environmental differences were possible and feasible to present, the screening has *at least* identified changes in organisational practices both at the procuring agency and at the contractors that seem to influence the environmental performance through a not straightforward interplay between organisational practices and technology, material and energy. This includes, among other:

- Renewal or not of procurement contracts and its environmental impact through fulfilment degree of environmental requirements and lacking transfers of general knowhow

- Centralisation of contractors activities and its environmental impacts through increased length of transports

- Fragmentation of procurement governance and environmental impacts through making it more difficult to have a held together approach to the often to many other organisational practices that determine environmental impacts

Further, these practices and the in addition identified practice seem to have been dependent on each other. A thorough nodal LCA organisation study might result in an understanding of how some of these and other practices are related and their magnitudes of influence on environmental performance. A reason why it may not be the result is the seeming not straightforward relations between the practices. Based on the list just prior to this paragraph, for example, renewal or not of procurement contracts seemingly depended via use of procurement or not on among other both centralisation of contractors' activities and fragmentation of procurement governance. These causes and effects likely to a moderate to high degree were difficult to discern due to multiple highly with each other involved causes, and that case studies probably only could cover certain specific modes of these practices. On the other hand, such a result seems in itself to be moderately to highly relevant for pointing to the usefulness of searching for complementing approaches to direct changes to the organising for considerably lowering the environmental impacts caused by environmentally ineffective organising. Finally, the ratio between the occurrence of results useful for concrete actions and this pointing towards complementing approaches seems for product life cycle environmental performances of operation and routine maintenance of roads with road

administration areas used in Sweden as nodes to be moderately difficult to predict. Further, the taken together gain of these results have been indicated to be moderate compared to using a screening approach. The components and overall findings on this reasoning on choosing between a screening and a thorough nodal LCA organisation study for this product type and this type of nodes is presented in Table 9.6, further on in this sub-chapter.

Table 9.6: Overview of findings from reasoning on differences in usefulness between a screening and a thorough nodal LCA organisation study for product life cycle environmental performances of operation and routine maintenance of roads with road administration areas used in Sweden as nodes

Useful findings from the screening nodal LCA organisation study – summary		Organisational practices changes at both the procuring agency and the contractors seem to have influenced environmental performance Identified not straightforward interplay between organising, technology, and materials and energy processes
Seeming gain of performing instead of screening a thorough nodal LCA organisation study	Environmental performance: Overall	Small
	Environmental performance: Per part of the system	Moderate
	Environmental performance: Over time	Moderate to large
	Organisational study	Moderate to large
	Producing a basis for carrying out concrete actions	Moderate to small
	Taken together: Magnitude of gain and its predictability based on the screening	Moderate gain Moderate predictability
	Taken together: Types of gain and their predictability based on the screening	Moderately to largely pointing to a need for complementing alternative approaches Moderately to little producing a basis for carrying out concrete actions Moderate to low predictability

Further, it may also be worth to mention that increased market competition could be seen as encouraging a more efficient use of resources and thus a lowering of environmental impacts. However, the road management test case indicates a specific situation where it may be unclear whether there is such a relationship.

10. OVERALL ANALYSIS

In this chapter, we synthesise the contents of the summary and analysis sub-chapters related to all of the six test cases. To begin, some overarching characteristics of the cases give a picture of their scopes in general and point out some fundamental differences between the different cases. First, the environmental impact from the life cycles of the types of products studied in relation to emissions and resource use occurring within a certain geographical area have been found to be mainly moderate but also up to very large. These geographical areas have been from Sweden up to a global coverage. Further, the study size of the properties test case differed from the other ones according to its reported comprehensive size. Regarding site-specific data collection, this was based on customer visits and web sites for the bowling and bus test cases, and on guided tours and one interview for the bread test case. Further, it was based on one guided tour and documents for the cement test case, on observations, interviews and documents for the properties test case according to reports, and on one simultaneous interview with representatives for the road test case. Regarding the environmental assessments used as bases for the cases, these where quantitative for the majority of the cases, but qualitative for the bus test case and mainly qualitative for the bowling test case. The level of site-specificity of these assessments varied from site-specific for the properties test case to publications on the sectors generally for the bowling and bus test cases, via publications on other sites for the other test cases. *Taking the overarching case characteristics together, the studied environmental impacts were found to be at least moderate, the approach to the properties case was different by being comprehensive, a majority of cases used quantitative bases for environmental performance, and data collection and site-specificity varied between cases.* The details of this overview is presented in Table 10.1, further on in this chapter.

Table 10.1: Overarching characteristics of the studied products and the studies of them

Test case	Products in general	Test case specific characteristics		
	Degree of environmental impact from the life cycles of the products in relation to emissions and resource use occurring within a certain geographical area	Study size	Site-specific data collection	Environmental assessments
Bowling	Moderate regarding the Western World		As customer and web sites	Qualitative mainly and partly using publications on bowling generally
Bread produced in bakeries	Moderate regarding Sweden		Guided tours and one interview	Quantitative using publications on other sites
Bus travel on intercity routes	Moderate regarding Northern Europe		As customer and web sites	Qualitative using publications on intercity buses generally
Cement	Very large regarding a Global perspective		One guided tour and documents	Quantitative using publications on other sites
Properties management	Moderate to large Regarding Northern Europe	Reportedly comprehensive studies used as a basis	Reported to be observations, interviews and documents	Reported as quantitative and site-specific
Road management	Moderate regarding Sweden		Simultaneous interview with representatives	Quantitative using publications on other sites

Regarding the different practices indicated to be of relevance for product life environmental performance in the six test cases, these have been found to overlap to a very low degree. The overarching categories used to present them also overlap to very little. This points to a need to study each different type of activity as well as potentially also each different product life cycle and the organising of it with an open mind and expecting previously not covered aspects of the organising to be found to be of environmental relevance. In Table 10.2, further on in this chapter, and overview is presented of the different practices identified in the here reported on project.

Table 10.2: Overview of the practices indicated to be of relevance for product life environmental performance

Bowling Bowling halls' practices	**Bread produced in bakeries**	**Bus travel on intercity routes** Bus service providers' practices	**Cement**	**Properties management**	**Road management**
Overall planning: Ceasing of business or not Equipment trend following degree Lunch provision or not Types of services provided: Disco bowling degree Restaurants and bars degrees Additional games and similar activities degrees Premises maintenance and planning: Lane maintenance degree Outdoor climate kept at distance degree	Purchasing of supplies at bakeries: Farming's environmental impacts control degree Supply transport optimisation degree Supply transport distance Production automation and product focus at bakeries: Automation degree Built together machinery degree Contamination prevention degree Bread thickness and baking Production intervention approaches at bakeries: Manoeuvring complexity of production and products degrees Manoeuvring flexibility of production degree Retailer aspects: Nationwide distribution or not Supermarkets as retailers or not Wrapping at bakeries, retailers, and consumers types and amounts Overproduction through planning or non-deliberately degrees	Driving style: Calmness and smoothness degrees Eco-driving training and discussions degrees Ticket sales: Sales office sizes Number of routes served by the ticket offices Use of electronic tickets degree and digital solution chosen for this Fuelling, cleaning, servicing, maintenance and repairs at the garage: Garage location Fleet management: Seats organisation differences on the buses Fleet age Scheduling differences	Negotiations between cement producers and environmental authorities: Production permit renewal procedure differences Production permit expiration criteria differences Cement plant maintenance planning: Organisational practices for handling technical problems at and operation of the plant differences	Energy-based services, account I: Types of windows related to cultural heritage Insulation, mechanical ventilation, and energy systems in relation to renovation differences Operation practise differences for energy system and ventilation Energy-based services, account II: Windows and doors kept open degrees Insulation difference and fire protection Ventilation installation difference Water-based services, account I: Toilet and renovation and emergencies, system knowledge and operation and maintenance differences Water taps and renovation and emergencies, system knowledge and operation and maintenance differences Washing machines, pipes, and drainage replacement differences, system knowledge level, and operation and maintenance differences Water-based services, account II: Toilets replacement difference Mixers replacement difference Pipes replacement difference	Management by the procurement contract holders: Renewal or not of procurement contracts Centralisation of contractors activities Management by procuring organisations: Fragmentation of procurement governance Centralisation degree of procuring agency

Regarding further characteristics of the organisational practices indicated to be of product life cycle environmental importance, eight to thirteen practices were indicated in each of four of the six test cases, while three and four, respectively, were indicated in the two remaining test cases. This is likely an effect of the combination of less on-site information collected and feasible to access in the latter two test cases, and the prominence of environmental pressure on and work in cement production. Thus, the usefulness or amount of effort needed when using the project approach here reported on may vary considerably between types of activities. Further, the indicated certainty of influence on environmental performance from each of the practices has generally been found to be around moderate or a little lower except for the higher certainty of this influence indicated for the practices identified in the properties management test case. Connections between practices found within each of the test cases have been found not easily to be discernible in four of the test cases, while for the bus travel and properties management test cases be non-discernible to a minority but considerable degree and to vary between rather well understood and rather easily discernible, respectively. The indicated strengths of connections between the practices within each test case have been found at least to a considerable degree to be moderate or stronger except in the bus travel test case, and to be mainly weak or moderate except for the bus travel and cement production. Further, in three of the six test cases one or more aspects were found to be major connections between the practices. Size of business was found to be the dominant such connection in the bowling test case. Renovation practices, Fambo's emergency oriented approaches, Fambo rationalisations leading to little prioritising on energy and water issues, and Fambo focus on flat standards were identified as most prominent connections presented in the publication on account I on properties management. Installation years of different energy and water systems, and ventilation and temperature aspects were found to be the most prominent connections stated in the publication on account II on properties management. Whether procurement was used or not was identified as the most prominent connection in the road management test case. Finally, it was found that four of the test cases were conditioned by certain aspects. In the case on bowling, these were considerable requirements regarding indoor space, strong building foundation and air conditions. In the bread case, these were short durability, and large environmental consequences from transports. In the cement case, these were one process to a very large degree dominating environmental impacts, and already high levels of environmental regulation and pressure on the production of the product. In the road management case, it was being carried out by market actors while being procured by a national agency. *Taking the further characteristics of the organisational practices indicated to be of product life cycle environmental importance together, the number of them per case varied considerably, and the certainty of influence on environmental performance by the practices were mostly found to be moderate or a*

little lower but higher for the properties case. Further, connections between practices were found for a majority of the test cases to be of considerable strength between many of the practices and not easily discernible, and that a majority of the test cases were conditioned by certain aspects. In Table 10.3, further on in this chapter, and overview is presented of these different aspects of the practices identified in the here reported on project.

Table 10.3: Different indicated aspects of the indicated environmentally relevant practices

Test case	Number of practices	Indicated certainty of environmental significance of each of the practices	Indicated connections between each of the practices			Characteristics that the practices were indicated to be dependent on
			Indicated understanding or discernibility of the connections	Indicated strengths of the connection	Indicated additional aspects of the connections	
Bowling	8	Moderate to low	Not necessarily discernible	Weak or moderate mainly, and strong for a small share	-	Considerable requirements regarding indoor space, strong building foundation, and air conditions
Bread produced in bakeries	13	Moderate approximately	-||-	Moderate mainly, weak for a considerable share, and strong for a small share	Size of business as the dominant connection	Short durability, and large environmental consequences from transports
Bus travel on intercity routes	9	Moderate generally	For a minority but considerable share of them not discernible	Not or very weakly mainly and weakly, moderately or strongly for smaller shares	-	-
Cement	3	Moderate approximately	Not necessarily discernible	Not or very weakly mainly, and strongly for a considerable share	-	One process to a very large degree dominating environmental impacts, impacts from this process depending on the number of halts of it, and already high levels of environmental regulation and pressure on the production of the product
Properties management, account I	6	High approximately	Rather good understanding	Moderately mainly, and strongly for a small share	Renovation practices, Fambo's emergency oriented approaches, Fambo rationalisations leading to little prioritising on energy and water issues, and Fambo focus on flat standards as most prominent connections	-
Properties management, account II	6	Moderate or high approximately	Rather easily discernible	Moderately or weakly mainly, and not or very weakly for a considerable share	Installation years of different energy and water systems, and ventilation and temperature aspects as most prominent connections	-
Road management	4	Moderate to low	Not necessarily discernible	Weakly mainly, and moderately for a considerable share	Whether procurement was used or not as the most prominent connection	Carried out by market actors while being procured by a national agency

Regarding seeming generic issues found in the covered practices indicated to be of relevance for product life environmental performance, a considerable number of such issues were found in the here reported on project. In each of the cement and road management test cases, five to six such issues were found, and in each of the other test cases, nine to twelve issues were identified. Further, these issues overlap each other only to a small extent. *Taking seeming generic issues found in the practices indicated to be of relevance for product life environmental performance, a considerable number of with each other only little overlapping such issues were found.* In Table 10.4, further on in this chapter, and overview is presented of these different aspects of the practices identified in the here reported on project.

Table 10.4: Overview of the seeming generic issues found in the covered practices indicated to be of relevance for product life environmental performance

Bowling	**Bread produced in bakeries**	**Bus travel on intercity routes**	**Cement**	**Properties management**	**Road management**
Found in bowling halls' practices	Found in bakeries' practices	Found in bus service providers' practices	Found in practices of authorities governing cement plants and at cement plants	Found in properties management practices	Found in road management practices at procurement contract holders and at procuring organisations
9 issues	12 issues	10 issues	6 issues	10 issues	5 issues
Ceasing of business Trend following Environmental impact of a function in relation to other by it influenced or to it alternative functions Offers that are provided in addition to the core offer Fill rates Scheduling Maintenance level Sudden break-down unless sufficient maintenance Premises layout	Size of business Level of control of upstream activities Share of products with input materials with considerably different characteristics than the product studied Supply differentiation Connection between location and size Complexity and flexibility of production and products Outsourcing due to difficulties handling external developments Quality and its reliability Retailer types Management during organisational growth Coordination frequency Planned overproduction	Operation Training for environmentally less impacting operation Staff interaction Space utilisation Coordination with activities within other product life cycles affected by the organisation Provision of electronic services Type of electronic services Co-location of servicing facilities in relation to the delivery of the main product Age of equipment Adaptation to activities external to the organisation's product life cycles	Repeated interaction Types of instruments used when thorough demands are made by environmental authorities Length of time between thorough environmental demands Flexibility of what the work force performs Coordination of work force A crisis leading to changed organisational practices	<u>Account I:</u> Handling of seemingly conflicting aspects Rationalisation Co-ordination of measures of which some affect environmentally impacting devices Cyclic, continuous, emergency-driven, or needs adjusted actions Client demands contrary to following demands of the material and energy systems Knowledge of technical systems and of their performances <u>Account II:</u> Users' actions Side effects of measures performed for other reasons than adjusting the environmentally impacting properties of material and energy systems Year of installation Year of replacement	The effect of using or not using procurement Organisational discontinuity Increased transports from centralising Organisational fragmentation Centralisation and learning about environmental aspects

Regarding seeming importance of the generic issues for understanding each of the practices indicated to be of relevance for product life environmental performance, this was found to vary between high and low between the different test cases. In the bread and bus travel cases a smaller share of these relations were found to be very important, while this share was identified to be considerable in the other test cases. Further, a majority of the relations were found to be of low or no importance in the cases on bread and bus travel and for the properties management test case's account I. In Table 10.5, further on in this chapter, and overview is presented of the seeming importance of these generic issues for understanding each of the practices.

Table 10.5: Seeming importance of the generic issues for understanding each of the practices indicated to be of relevance for product life environmental performance

Test case	
Bowling	Moderate, high, or very high to considerable degrees and none or low to a small degree
Bread produced in bakeries	None or low to a majority degree and moderate, high, or very high to smaller degrees
Bus travel on intercity routes	None or low to a majority degree and moderate, high, or very high to smaller degrees
Cement	None or low or very high to considerable degrees, and high to a small degree
Properties management, account I	Very high to a majority degree, none or low to a considerable degree, and high to a small degree
Properties management, account II	None or low to a majority degree, and very high to a considerable degree
Road management	None or low, moderate, or very high to considerable degrees

Regarding through the project here reported on identified product life cycle environmental effects of different states of each practice, the clarity of these was found to vary between low and high between the cases and to be low in a majority of the test cases. For all test cases besides bus travel and properties management, it was found to be not clear whether each such state led to increased, decreased or similar product life cycle environmental impacts. In the case on bus travel, this was identified to be not clear for a minority but considerable share of the practices. In the properties management case, it was found to be clear for account I and clear for half of the practices in account II. The size of the effects on product life cycle environmental impacts were found not to be clear in the bus travel test case, and in the properties management test case to be

clear for account I and clear for half of the practices in account II. In Table 10.6, further on in this chapter, and overview is presented of the identified product life cycle environmental effects of different states of each practice.

Table 10.6: Through the project identified product life cycle environmental effects of different states of each practice

Test case	Increased, decreased or similar product life cycle environmental impacts	Size of effect on product life cycle environmental impacts
Bowling	Not clear	-
Bread produced in bakeries	-||-	-
Bus travel on intercity routes	For a minority but considerable share of them not clear	Not clear
Cement	Not clear	-
Properties management, account I	Clear	Clear
Properties management, account II	Clear for half of them	Clear for half of them
Road management	Not clear	-

Regarding overall usefulness of screening and thorough nodal LCA organisation studies, respectively, generally the screenings were found to be considerably useful but instead performing thorough studies was indicated to provide considerable additional usefulness although the level and type of this addition were generally found to be difficult to predict. In relation to the five test cases besides the properties case, organisational aspects were identified as considerably influencing environmental performance. These aspects consist of business models used, operating business approaches, innovation approaches, management and operation of a main technical component, and organisational processes and practices. Further, in relation to these five test cases, often more but in two cases less intricate interplays were identified between organising or management and technology and in most cases materials and energy processes. The gains of instead of a screening performing a thorough nodal LCA organisation study was indicated to be at least of moderate magnitude but the unpredictability of this magnitude was in relation to a majority of the test cases moderate. These gains, although not easily determinable and varying between the test case, were found to be a combination of reaching explanations of the quantitative environmental effects of certain states of organisational practices and pointing to a need for

alternative approaches to handle difficulties to discern environmental effects of different organisational practices. In the properties test case, three overarching uses of findings reported were identified. First, practices were reported as explaining overall from quantitative records extracted differences in energy and water use levels and variations in three out of four cases. Second, these practices were presented as in straightforward ways being related to each other through a few different overarching management approaches. Third, an organisational understanding was necessary for explaining all of the covered differences in technology that influenced energy and water were use. Further information on these aspects in relation to the different test cases is presented in Table 10.7, further on in this sub-chapter.

Table 10.7: Usefulness of nodal LCA organisation studies. Combination of an overview of findings from reasoning on differences in usefulness between a screening and a thorough nodal LCA organisation study based on five of the test cases, and a presentation of the from reports identified usefulness of thorough nodal LCA organisation study covered in the properties management test case

Type of product and type of nodes	Usefulness either of a screening nodal LCA organisation study, or in the properties management case of a thorough nodal LCA organisation study	Seeming gain of performing instead of screening a thorough nodal LCA organisation study	
		Magnitude of gain and its predictability based on the screening	Types of gain and their predictability based on the screening
Bowling Bowling halls in Sweden	Business model differences seem to have influenced environmental performance Identified intricate interplay between organising, technology, and materials and energy processes	Moderate gain Moderate predictability	Moderately to largely pointing to a need for complementing alternative approaches Moderately to little producing a basis for carrying out concrete actions Moderate to low predictability
Bread Bakeries in Sweden	Operating business approach differences seem to have influenced environmental performance Identified intricate interplay between organising, technology, and materials and energy processes	Moderate gain Moderate predictability	Moderately producing a basis for carrying out concrete actions Moderately pointing to a need for complementing alternative approaches Moderate predictability
Bus travel on intercity routes Bus routes in Scandinavia	Business models operated by and innovation and fleet management approaches of the bus travel operator companies differed in ways seem to have influenced environmental performance Identified intertwined interplay between management and technology	Moderate to large gain Moderate to high predictability	Moderately to largely producing a basis for carrying out concrete actions Little pointing to a need for complementing alternative approaches Moderate to high predictability
Cement Cement plants in Sweden	Organisational processes differences seem to have influenced environmental performance Identified intricate interplay between organising, technology, and materials and energy processes	Moderate to large gain Moderate predictability	Moderately producing a basis for carrying out concrete actions Moderately pointing to a need for complementing alternative approaches Moderate to low predictability
Properties management Properties	Practices were reported as explaining overall from quantitative records extracted differences in energy and water use levels and variations in three out of four cases These practices were presented as in straightforward ways being related to each other through a few different overarching management approaches An organisational understanding was necessary for explaining all of the covered differences in technology that influenced energy and water were use	Not applicable	Not applicable
Road management (operation ad routine maintenance of roads) Road administration areas used in Sweden	Organisational practices changes at both the procuring agency and the contractors seem to have influenced environmental performance Identified not straightforward interplay between organising, technology, and materials and energy processes	Moderate gain Moderate predictability	Moderately to largely pointing to a need for complementing alternative approaches Moderately to little producing a basis for carrying out concrete actions Moderate to low predictability

Regarding additional aspects identified through the project here reported on, clear such ones were found in four of the test cases. These aspects cover a nuancing example to singular environmental debate on food discarding, a sector being a bridge to larger influences on environmental impacts, the combined type of study likely useful in an already highly environmentally targeted sector, and highlighting two likely environmentally opposing sides of competition. In Table 10.8, further on in this chapter, and overview is presented of these additional aspects.

Table 10.8: Additional aspects indicated to be related to the test cases

Test case		
Bowling	-	-
Bread produced in bakeries	Nuancing example to singular debate	Example of how the environmental management debate may be too simplified regarding food discarding
Bus travel on intercity routes	Bridge to larger influences on environmental impacts	Test area for new drive-trains and fuels with larger further consequences
Cement	Combined study likely useful	Using a combination of environmental performance and organising may be necessary to further an already heavily environmentally targeted sector
Properties management	-	-
Road management	Two environmental sides of competition	Highlights that increased market competition either may lead increased efficiency and environmental efforts, or to discontinuity of practices with lower environmental impacts

Summarising this chapter, overviews have been presented regarding several aspects about the six test cases and their usefulness. Concisely, the following findings have been pointed out on eight types of aspects:

1. Regarding overarching case characteristics, the studied environmental impacts were found to be at least moderate, the approach to the properties case was different by being comprehensive, a majority of cases used quantitative bases for environmental performance, and data collection and site-specificity varied between cases.

2. Regarding the different practices indicated to be of relevance for product life environmental performance in the six test cases, these have been found to overlap to a very low degree.

3. Regarding further characteristics of the organisational practices indicated to be of product life cycle environmental importance together, the number of them per case varied considerably, and the certainty of influence on environmental performance by the practices were mostly found to be moderate or a little lower but higher for the properties case. Further, connections between practices were found for a majority of the test cases to be of considerable strength between many of the practices and not easily discernible, and that a majority of the test cases were conditioned by certain aspects.

4. Regarding seeming generic issues found in the practices indicated to be of relevance for product life environmental performance, a considerable number of with each other only little overlapping such issues were found.

5. Regarding seeming importance of the generic issues for understanding each of the practices indicated to be of relevance for product life environmental performance, this was found to vary between high and low between the different test cases.

6. Regarding through the project here reported on identified product life cycle environmental effects of different states of each practice, the clarity of these was found to vary between low and high between the cases and to be low in a majority of the test cases.

7. Regarding overall usefulness of screening and thorough nodal LCA organisation studies, respectively, generally the screenings were found to be considerably useful but instead performing thorough studies was indicated to provide considerable additional usefulness although the level and type of this addition were generally found to be difficult to predict.

8. Regarding additional aspects identified through the project here reported on, clear such ones were found in four of the test cases.

11. DISCUSSION

The project here reported on is in this chapter discussed regarding the feasibility of its design for being able to fulfil its aim and whether and if so which potential implications that the project points towards for considerably reducing environmental impacts in society. Whether the aim of the project could be fulfilled has been identified to depend on how well the findings from the empirical studies can be used for generalisations. It has been attempted to screen how the organising of nodal technical processes in product life cycles influence the environmental performance of these cycles.

Critical factors identified for this issue are types of activities, geographical dependency, time scope covered, research techniques for data collection, as well as broadness and depth in data collection. The types of activities cover a range that has deliberately been chosen to be broad and they have been found to be part of activities with not negligible environmental impacts. Due to the combination of these conditions with that the focus has been on generic aspects such as potentially many different organisational aspects being of relevance, the scope of the project may be relevant in addition to a Swedish perspective for a broader geographical coverage such as the Western World or the economically developed countries.

Further, a longer time scope was only a basis of the project regarding the properties management test case but was encountered in most of the other test cases as well. However, a to a considerable degree different type of results were reported on the properties management test case than for the other test cases regarding particularly in three of its four parts fully identifying links between certain environmental performance and organisational aspects. Thus, if such a longer time perspective is used and carried out using the considerably more through study reported to be used in the properties management test case than in the other test cases a more full picture of the major part of environmental performance of the product life cycles being clearly linked to organisational aspects may be found. On the other hand, this may not necessarily be the situation since potentially the properties management test case was more straightforward with a limited number of technical intermediaries via which the organising in seemingly mainly linear ways influenced environmental performance.

Regarding research techniques for data collection, these have been literature studies, interviews, observation, and document studies. Observation makes it possible to identify actions performed in practice, but may be less accurate and useful due to the presence of a researcher potentially influencing the practices and in order to identify for example quantitative measurements and to create an overview of a larger set of practices. Interviews may assist in fulfilling some of these shortcomings but may be difficult to validate, may only cover the limited views by the approached interviewees. Taken together, many of the practices identified in the

project here reported on should be treated *potentially* as considerably influencing product life cycle environmental performance.

Further, broadness and depth in the data collection were necessarily limited due to the screening characteristic of the project here reported on. Particularly for the nodal sites where a large number of persons or technical processes were involved, only a limited perspective and depth of the sites could be covered. Thus, a more broad or in-depth study may either reveal an even larger amount of organisational practices that have not necessarily discernible influence on environmental performance or a more clear picture regarding this.

Finally, regarding the design of the project here reported on, the screening characteristic of the project necessarily have limitations due to for example limitations in the research techniques used and its limited scope and depth. However, these limitations can be seen as prerequisites for the findings resulting from the project. This covers both the identification of the large number of organisational practices with indicated large influence on environmental performance, and the reaching of the overarching indications on these practices and their seeming variation between different activities and the likely difficulties to discern their influence on environmental performance.

Regarding whether and if so which potential implications that the project here reported on points towards for considerably reducing the environmental impacts caused by society and based on the discussion this far, organising seems likely to have large and not necessarily discernible influences on environmental performance. This seems to be caused by a combination of the many and often not to each other clearly visible technical processes along product life cycles, a large number of different environmental impacts caused by these cycles, and the sometimes many and between activities differing practices of organising connected to each other and influencing this environmental performance. The indicated differences between organising of different activities points to that a straightforward and seemingly easily controllable connection between organising and its product life cycle(s) environmental performance need not indicate more generally that such relations can be discerned or controlled in other activities.

The complexity inside organisations and the difficulty to map them identified in large parts of the project here reported on, could be interpreted as suggesting that it would be important with an environmentally driven internal work in organisations and along product life cycles since outsiders cannot easily suggest environmentally effective measures. The in the project indicated differences between sectors could further suggest this. On the other hand, internal organisational knowledge about environmental issues and pathways and the feasibility of this type of cooperation between different actors along product life cycles are likely to be a limiting factor for the environmental effectiveness of this approach. In addition, a considerable pressure from the public may be needed for the involved actors to be motivated enough to perform this.

A complementing or alternative approach that might seem to be a way to handle this is by external to the core product life cycle organising assisting or steering these processes. However, this may require large amounts of such experts and thus it may be difficult to motivate such expenses. Generally, also here it might be necessary with a considerable pressure from the public.

Further, one key factor seems to be the combination of important environmental impacts being caused far from material and energy uses that are determined by in many activities plentiful and not necessarily discernible organising. One option that appears potentially to be able to tackle this could be to let the effects of environmental impacts be translated into the general currency of money and be paid for directly at the specific place where the environmentally affecting resource extraction or emission occur and cover these local costs globally. This may also however not necessarily be feasible to carry out due for example the difficulties of performing international governance and may as well require a considerable pressure from the public.

Finally, even if internal, expertise, or monetary environmental local control is exercised, the project here reported on suggests that the environmental effects of a considerable share of actions still may not be possible or feasible to foresee.

12. CONCLUSION

Through the screening project here reported several findings have been indicated based on studies of relations between product life cycle environmental performance and organising traced from technical processes that have central roles by connecting many inputs and outputs of materials and energy to these life cycles. A large number of practices of this organising have been indicated potentially to considerably influence product life cycle environmental performance. These organisational practices have been indicated to vary considerably between different activities both regarding the practices themselves and regarding the discernibility of their relations to each other and of their influence on environmental performance. This has been studied using a nomenclature and visualisations that strongly build on the LCA method in order to make the approach as readily available as possible to the LCA related audience. Regarding overall usefulness of screening and thorough nodal LCA organisation studies, respectively, generally the screenings were found to be considerably useful but instead performing thorough studies was indicated to provide considerable additional usefulness although the level and type of this addition were generally found to be difficult to predict.

In addition, the project approach and the results generated have been discussed regarding how useful the indicated findings are in relation to the studied phenomena and regarding its potential to point towards more overarching ideas on considerable reductions of society's environmental impacts. The screening characteristic of the project necessarily have limitations due to for example limitations in the research techniques used and its limited scope and depth. However, these limitations can be seen as prerequisites for the findings resulting from the project. This covers both the identification of the large number of organisational practices with indicated large influence on environmental performance, and the reaching of the overarching indications on these practices and their seeming variation between different activities and the likely difficulties to discern their influence on environmental performance. Further, a few ideas have been discussed regarding potentially environmentally effective handling the indicated many and between activities varying environmentally considerably affecting organisational practices from which influence on environmental influence may not necessarily be discernible. These cover internally driven environmental work within the organising connected to and along product life cycles, substantial amounts of assistance in such work from external experts, and an approach to focus of with a global coverage letting the local activities where the environmentally impacting resource use and emissions occur be monetary targeted. The actual feasibility of each of these approaches, however, seem more or less limited and a uniting requirement seem to be a considerable pressure from the public. Finally, even if such considerable undertakings are made the project here reported on suggests that the environmental effects of a considerable share of actions still may not be possible or feasible to foresee.

REFERENCES

Adolfsson, P. (2005). Environment's many faces: Organizing and translating objects in Stockholm. In Czarniawska, B. and G. Sevón (eds) *Global ideas*. Oslo: Liber.

Adolfsson, P. (2007). Questioning organizational boundaries? The implementation of the EU-WFD in Sweden. *NESS conference*, 18–20 June 2007, Oslo.

Algehed, J. and K. Winnes (2010) *Miljökultur: Vad vet forskarna om kulturens och tjänsternas miljöpåverkan* (SP Rapport 2010:62). Borås, Sweden: SP Technical Research Institute of Sweden.

Andersson, K. and T. Ohlsson (1999). Life cycle assessment of bread produced on different scales. *International Journal of Life Cycle Assessment, 4*(1): 25–40.

Åsberg, C., M. Hultman, and F. Lee (2012). Posthumanistisk ordlista. In Åsberg, C., M. Hultman, and F. Lee (eds) *Posthumanistiska nyckeltexter* (pp. 201–218). Lund, Sweden: Studentlitteratur.

Ayres, R.U. and L.W. Ayres (Eds) (2002). A handbook of industrial ecology. Cheltenham: Elgar.

Baumann, H. (2004). Environmental assessment of organising: Towards a framework for the study of organisational influence on environmental performance. *Progress in Industrial Ecology – An International Journal 1*(1/2/3): 292–306.

Baumann, H. (2008). Simple material relations handled by complicated organisation by or 'how many organisations does it take to change a lightbulb?' *What is an organization? Materiality, Agency and Discourse*, 21–22 May 2008, Montréal, Canada.

Baumann, H. (2012). Using the life cycle approach for structuring organizational studies of product chains. *The 18th Greening of Industry Network Conference*, 22–24 October 2012, Linköping, Sweden.

Baumann, H. and A.-M. Tillman (2004). *The hitch hiker's guide to LCA: An orientation in life cycle assessment methodology and application*. Lund, Sweden: Studentlitteratur.

Boons, F. and J. Grenville-Howard (Eds) (2009). *The social embeddedness of industrial ecology*. Cheltenham, MA: Edward Elgar.

Braschkat, J., A. Patyk, M. Quirin, and G.A. Reinhardt (2003). Life cycle assessment of bread production – a comparison of eight different scenarios. *Proceedings from the 4th International Conference on Life Cycle Assessment in the Agri-food Sector*, 6–8 October, 2003, Bygholm, Denmark.

Brunklaus, B. (2005). *Organisational background to environmental impacts: Field study on housing management in Gothenburg*. Licentiate of engineering thesis. Environmental Systems Analysis, Chalmers University of Technology, Gothenburg, Sweden.

Brunklaus, B. (2008). *Organising matters for the environment: Environmental studies on housing management and buildings*. PhD thesis. Environmental Systems Analysis, Chalmers University of Technology, Gothenburg, Sweden.

Brunklaus, B. (2009a). Does organising matter? Tracing connections to environmental impacts in different housing estates. *Progress in Industrial Ecology – An International Journal 6*(2): 120–134.

Brunklaus, B. (2009b). *Litteraturstudie kring miljöpåverkan av immateriell konsumtion, dvs LCA av tjänstekonsumtion*. Internal report. Gothenburg, Sweden: Environmental Systems Analysis, Chalmers University of Technology.

Callon, M. (2001). Actor network theory. In Smelser, N.J. and P.B. Baltes (eds) *International encyclopedia of the social & behavioral sciences* (pp. 62–66). Amsterdam: Elsevier.

Czarniawska, B. (2004). On time, space, and action nets. *Organization 11*(6): 773–791.

Czarniawska, B. (2005). *En teori om organisering*. Lund, Sweden: Studentlitteratur.

Faith-Ell, C., B. Balfors, and L. Folkeson (2006). The application of environmental requirements in Swedish road maintenance contracts. *Journal of Cleaner Production 14*(2): 163–171.

FAO (Food and Agriculture Organization of the United Nations) (2011). *Global food losses and food waste – Extent, causes and prevention*. Rome.

FCCC (Framework Convention on Climate Change) (2013). *National greenhouse gas inventory data for the period 1990–2011*. United Nations

Finnveden, G., M.Z. Hauschild, T. Ekvall, J. Guinée, R. Heijungs, S. Hellweg, A. Koehler, D. Pennington, and S. Suh (2009). Recent developments in life cycle assessment. *Journal of Environmental Management 91*(1): 1–21.

Fuglestvedt, J., T. Berntsen, G. Myhre, K. Rypdal, and R.B. Skeie (2008). Climate forcing from the transport sectors. *Proceedings of the National Academy of Sciences of the United States of America 105*(2): 454–458.

Glaser, B.G. and A.L. Strauss (2006). *The discovery of grounded theory: Strategies for qualitative research*. New Brunswick, NJ: Transaction Publishers.

Huntzinger, D.N. and T.D. Eatmon (2009). A life-cycle assessment of Portland cement manufacturing: Comparing the traditional process with alternative technologies. *Journal of Cleaner Production 17*(7): 668–675.

IPCC (Intergovernmental Panel on Climate Change) (2007). *Climate change 2007: Synthesis report*.

IPCC (Intergovernmental Panel on Climate Change) (2014). *Climate Change 2014: Mitigation of Climate Change*.

ISO (International Standard Organisation) (2006a). *Miljöledning - livscykelanalys - krav och vägledning (ISO 14044:2006). Environmental management - life cycle assessment - requirements and guidelines (ISO 14044:2006)*. Stockholm: SIS.

ISO (International Standard Organisation) (2006b). *Miljöledning - livscykelanalys - principer och struktur (ISO 14040:2006). Environmental management - life cycle assessment - principles and framework (ISO 14040:2006)*. Stockholm: SIS.

Journal of Cleaner Production (2015). *Journal of Cleaner Production - Elsevier*. http://www.journals.elsevier.com. Accessed on 12 January 2015.

Journal of Industrial Ecology (2014). *Journal of Industrial Ecology - Overview - Wiley Online Library*. Yale University. http://onlinelibrary.wiley.com. Accessed on 12 January 2015.

Kallio, T. and P. Nordberg (2006). The evolution of organizations and natural environment discourse: Some critical remarks. *Organization & Environment 19*(4): 439–457.

Klöpffer, W. (2014). Introducing Life Cycle Assessment and its presentation in 'LCA Compendium'. In Klöpffer, W. (ed) *Background and future prospects in life cycle assessment* (pp. 1–38). Springer.

Korhonen, J. and P. Strachan (2004). Editorial: Towards progress in industrial ecology. *Progress in Industrial Ecology – An International Journal 1*(1/2/3): 1–23.

Latour, B. (1987). *Science in action: How to follow scientists and engineers through society*. Cambridge, MA: Harvard University Press.

Liljegren E. (2003). *Konkurrensutsättning av Vägverkets drift- och underhållsverksamhet: En studie av effekterna på kvalitet, transaktionskostnader och organisation*. PhD thesis. Institutionen för infrastruktur, Kungliga Tekniska högskolan, Stockholm.

Lindkvist, M. and H. Baumann (2010). The environmental significance of management practices: Exploring the eco-efficiency of 6 cases. *The 14th European Roundtable on Sustainable Consumption and Production Conference and the 6th Environmental Management for Sustainable Universities Conference*, 25–29 October 2010, Delft, the Netherlands.

Lindkvist, M. and H. Baumann (2014). *A review of social science in five industrial ecology journals* (Report / Division of Environmental Systems Analysis, Chalmers University of Technology, no 2014:13). Gothenburg, Sweden: Environmental Systems Analysis, Chalmers University of Technology.

Lundberg, Ö. (2008). *Management matters: Linking management of buildings to environmental impacts in a pilot study of supermarket buildings* (Report – Department of Environmental Systems Analysis, Chalmers University of Technology, no. 2008:3). Gothenburg, Sweden: Environmental Systems Analysis, Chalmers University of Technology.

Molina-Azorín, J.F. and M.D. López-Gamero (2014). Mixed methods studies in environmental management research: Prevalence, purposes and designs. *Business Strategy and the Environment*. DOI: 10.1002/bse.1862.

Nationalencyklopedin (2001). *Bageriindustri*. Nationalencyklopedin. http://www.ne.se. Accessed on 5 May 2010

Naturvårdsverket (2015). *Utsläpp av växthusgaser från inrikes transporter 1990-2013: Uppdaterad 11 mars 2015*. http://naturvårdsverket.se. Accessed on 19 March 2015.

Piasecki, B. (1992). Industrial ecology: An emerging management science. *Proceedings of the National Academy of Sciences USA, 89*: 873–875.

Rex, E. (2007). *Produktens eller samhällets miljöproblem? Om miljöfrågans hantering och kommunikation inom Volvo Lastvagnar* (Report – Department of Environmental Systems Analysis, Chalmers University of Technology, no. 2007:19). Gothenburg, Sweden: Environmental Systems Analysis, Chalmers University of Technology.

Roy, P., D. Nei, T. Orikasa, Q. Xu, H. Okadome, N. Nakamura, et al. (2009). A review of life cycle assessment (LCA) on some food products. *Journal of Food Engineering, 90*: 1–10.

SCB (Statistics Sweden) (2013). *Befolkningsstatistik i sammandrag*. SCB. http://www.scb.se. Accessed on 8 Mars 2013

SIK (The Swedish Institute for Food and Biotechnology) (2009). *Klimatpåverkan från bröd – kommunikationsunderlag. P80427. Utdrag ur rapport till Brödinstitutet januari 2009*.

Statens Jordbruksverk (2015). *Jordbruksmarkens användning 2014: Slutlig statistik* (Statistisk meddelanden, JO 10 SM 1501).

Stripple, H. (2001). *Life cycle assessment of road: A pilot study for inventory analysis: Second revised edition*. Stockholm: IVL Swedish Environmental Research Institute.

Tengström, J. and F. Izurieta (2010). *LCA of stage performances: Life cycle assessment of an opera and a theatre stage performance* (Report – Department of Environmental Systems Analysis, Chalmers University of Technology, no. 2010:8). Gothenburg, Sweden: Environmental Systems Analysis, Chalmers University of Technology.

Tung, A., K Baird, and H. Schoch (2014). The relationship between organisational factors and the effectiveness of environmental management. *Journal of Environmental Management, 144*: 186–196.

Ukidwe, N.U. (2005). *Thermodynamic input-output analysis of economic and ecological systems for sustainable engineering*. PhD thesis. Graduate Program in Chemical Engineering, the Ohio State University.

UNFCCC (United Nations Framework Convention for Climate Change) (2005). *Sixth compilation and synthesis of initial national communications from Parties not included in Annex I to the Convention* (FCCC/SBI/2005/18/Add.2).

UNFCCC (United Nations Framework Convention for Climate Change) (2014). *National greenhouse gas inventory data for the period 1990–2012* (FCCC/SBI/2014/20).

Van Holderbeke, M., N. Sanjuán, T. Geerken, and D. de Vooght (2003). The history of bread production: Using LCA in the past. *Proceedings from the 4th International Conference on Life Cycle Assessment in the Agri-food Sector*, 6–8 October, 2003, Bygholm, Denmark.

Vazquez, D.A. and C. Liston-Heyes (2008). Corporate Discourse and Environmental Performance in Argentina. *Business Strategy and the Environment, 17*: 179–193.

Vold, M. and A. Rønning (1995). *LCA on cement and concrete – Main report*. Stiftelsen Østfoldforskning.

Von Bahr, B., O.J. Hanssen, M. Vold, G. Pott, E. Stoltenberg-Hansson, and B. Steen (2003). Experiences of environmental performance evaluation in the cement industry: Data quality of environmental performance indicators as a limiting factor for benchmarking and rating. *Journal of Cleaner Production, 11*(7): 713–725.

WRI (World Resource Institute) (2005). Ecosystems and human well-being: Synthesis. Millennium ecosystem assessment. Washington, DC: Island Press.

SOURCES

Bowling

Visits as a customer

Majorna bowling (2010). Gothenburg, Sweden, 26 January 2010.

Star (2010). Gothenburg, Sweden, 20 May 2010.

Valhalla Bowling (2010). Gothenburg, Sweden, 15 April 2010.

Valhalla Bowling (2012). Gothenburg, Sweden, 7 June 2012.

Internet sources

Bowltech Sweden (2008a). *Bowltech Sweden AB: Banbehandling - Tvättmedel*. http://www.bowltech.se. Accessed on 7 May 2012.

Bowltech Sweden (2008b). *Bowltech Sweden AB: Bowltech's hyrskor & tillbehör*. http://www.bowltech.se. Accessed on 7 May 2012.

Brunswick (2012a). *Bowling center products*. http://www.brunswickbowling.com. Accessed on 2 October 2012.

Brunswick (2012b). *House balls | Brunswick*. http://www.brunswickbowling.com. Accessed on 8 May 2012.

Brunswick (2012c). *Lanes | Brunswick*. http://www.brunswickbowling.com. Accessed on 8 May 2012.

Brunswick (2012d). *Preplanning guide*. http://www.brunswickbowling.com. Accessed on 4 May 2012.

Eniro (2012). *Bowling Göteborg - Gula sidorna på eniro.se*. http://gulasidorna.eniro.se. Accessed on 7 May 2012.

Kegel (2012a). *Kegel – Bowling solutions, lane conditioners. Lane machine, lane conditioning, lane clearing, lane pattern adjustments, sanction technology, KOSI, cut the cord, Lithium Battery, power cord*. http://www.kegel.net. Accessed on 8 May 2012.

Kegel (2012b). *Kegel – Bowling solutions. Lane maintenance, lane machines, lane conditioning, lane cleaning, lane supplies, spare parts, training, clinics, seminars, Kustodian, sanction technology, bowling center, latest products, lane pattern, distributors, software, pattern library, Crossfire, Firebird, Standard Elite*. http://www.kegel.net. Accessed on 8 May 2012.

Kegel (2012c). *Kegel – Bowling solutions, sanction technology overview. Lane machine, lane conditioning, lane clearing, lane pattern adjustments, sanction technology, KOSI, cut the cord, Dry Cell Battery, power cord*. http://www.kegel.net. Accessed on 8 May 2012.

Majorna bowling (2012a). *Bar - Majornas bowling*. http://www.majornabowling.se. Accessed on 7 May 2012.

Majorna bowling (2012b). *Barnkalas - Majornas bowling*. http://www.majornabowling.se. Accessed on 7 May 2012.

Majorna bowling (2012c). *Cityligan - Majornas bowling*. http://www.majornabowling.se. Accessed on 7 May 2012.

Majorna bowling (2012d). *Majorna bowling - Inter Bowling i Göteborg*. http://www.majornabowling.se. Accessed on 7 May 2012.

Majorna bowling (2012e). *Mat & bowling - Majornas bowling*. http://www.majornabowling.se. Accessed on 7 May 2012.

Majorna bowling (2012f). *Priser & bokning - Majornas bowling*. http://www.majornabowling.se. Accessed on 7 May 2012.

QubicaAMF (2011a). *Lifestyle furniture – Bowling equipment manufacturer – QubicaAMF*. http://www.qubicaamf.com. Accessed on 13 June 2012.

QubicaAMF (2011b). *MASQ collection – Setting up a bowling alley – QubicaAMF*. http://www.qubicaamf.com. Accessed on 13 June 2012.

QubicaAMF (2011c). *Option ball returns – QubicaAMF*. http://www.qubicaamf.com. Accessed on 8 May 2012.

QubicaAMF (2011d). *Pins – Bowling equipment – QubicaAMF*. http://www.qubicaamf.com. Accessed on 8 May 2012.

QubicaAMF (2011e). *Velcro rental shoes – Bowling equipment – QubicaAMF*. http://www.qubicaamf.com. Accessed on 11 June 2012.

QubicaAMF (2011f). *Video MASQ system – Setting up a bowling alley – QubicaAMF*. http://www.qubicaamf.com. Accessed on 13 June 2012.

QubicaAMF (2012). *Scoring and center management systems*. http://www.qubicaamf.com. Accessed on 2 October 2012.

SBHF (2012). *Hallar - SBHF*. Sveriges Bowlinghallars Förbund. http://www.sbhf.se. Accessed on 7 May 2012.

Star (2012a). *Bar | Star Bowling*. http://www.starbowling.se. Accessed on 7 May 2012.

Star (2012b). *Bowling | Star Bowling*. http://www.starbowling.se. Accessed on 7 May 2012.

Star (2012c). *Konferens | Star Bowling*. http://www.starbowling.se. Accessed on 7 May 2012.

Star (2012d). *Star Steakhouse: A culinary roadtrip*. Star.

Star (2012e). *Välkommen till Star :: Bowling :: Konferens :: Restaurang*. http://www.starbowling.se. Accessed on 7 May 2012.

VBS Bowling (2012a). *VBS Bowling AB - Brunswick GSX-maskin*. http://www.vbsbowl.com. Accessed on 8 May 2012.

VBS Bowling (2012b). *VBS Bowling AB - Revolution inom banbehandling*. http://www.vbsbowl.com. Accessed on 8 May 2012.

Bread produced in bakeries

Study visits and interviews

Adem, F. (2010). *Study visit to the Dahls bakery on Källhusgatan 5, Gothenburg, Sweden*. 25 February 2010.

Hedberg, K. (2010). *Study visit to the Pågen factory bakery on Olof Asklunds gata 21, Gothenburg, Sweden*. 16 March 2010.

Norrman, S. (2010). *Interview and study visit at the Ambrosia bakery on Sporregatan 21, Malmö, Sweden*. 21 January 2010.

Internet sources

Dahls (2012a). *Hitta närmaste butik*. http://dahlsbageri.se. Accessed on 14 February 2013.

Dahls (2012b). *Kontakt*. http://dahlsbageri.se. Accessed on 14 February 2013.

Pågen (2012a). *Kontakt*. http://www.pagen.se. Accessed on 14 February 2013.

Pågen (2012b). *Närodlat*. http://www.pagen.se. Accessed on 18 February 2013.

Bus travel on intercity routes

Internet sources

Eurolines (2015). *Explore Europe by road. 600+ destinations. 33 countries*. http://eurolines.com. Accessed on 18 March 2015.

Swebus (n.d.) . *Våra linjer*. http://www.swebus.se. Accessed on 18 March 2015.

Cement

Study visit

Sjöstrand, M. (2009). *Study visit to the Cementa cement plant in Skövde, Sweden*. 6 October 2009.

Environmental report sent to authorities

Cementa (2007) *Miljörapport för Cementa AB Skövdefabriken (1496-1102) år: 2006 version: 1*.

Cementa (2008a) *Cementa AB Degerhamnsfabriken: Miljörapport för år 2007*.

Cementa (2008b) *Miljörapport: För Cementa AB Skövdefabriken (1496-1102) år: 2007 version: 1*.

Court documentation on application for permit for increased production volumes

Växjö Tingsrätt (2007). *Deldom, mål nr M 2739-05*. Växjö Tingsrätt, Miljödomstolen: Växjö, Sweden.

Internet source

Cementa (n.d.). *Hållbarhetsredovisning 2007*.

Road management

Interview

Barresten, R. and M. Wester (2010). *Interview at the Swedish Transport Administration (Trafikverket), Gothenburg, Sweden*. 21 December 2010.

Internet sources

Trafikverket (2010a). *Driftområde Göteborg*. http://www.trafikverket.se. Accessed on 29 November 2010.

Trafikverket (2010b). *Driftområde Kungälv/Tjörn*. http://www.trafikverket.se. Accessed on 29 November 2010.

Trafikverket (2010c). *Driftområde Kungsbacka*. http://www.trafikverket.se. Accessed on 29 November 2010.

Trafikverket (2010d). *Om skötsel av vägar*. http://www.trafikverket.se. Accessed on 24 November 2010.

APPENDIX – DETAILED OVERVIEWS OF THE COVERED SIX TEST CASES

Table A.1: Overview of test case 1–3 and their sub-cases, including data collection

Test case	Sub-case	Location		Characteristics		Sub-case specific data collection	
		In common	Difference	In common	Difference	On site	Remotely
1 Bowling	Star	Sweden, Gothenburg, city centre periphery	North eastern	Medium sized bowling hall	-	Visit as customer, 2010	Hall website, 2012
	Majorna bowling	-||-	Western	-||-	-	-||-	-||-
	Valhalla Bowling	-||-	Eastern	-||-	-	Visit as customer, 2010; visit 2012	-||-
2 Bread produced in bakeries	Pågen	Sweden	Gothen-burg	-	Large-scale soft bread production	Study visit, 2010	Bakery company website, 2012
	Dahls	-||-	-||-	-	Medium-scale soft bread production	-||-	-||-
	Ambrosia	-||-	Malmö	-	Small-scale to medium-scale soft bread production	Study visit combined with interview, 2010	Bakery company website, 2014
3 Bus travel on intercity routes	Swebus Express	The route Sweden, Gothenburg – Norway, Oslo	-	-	Run by a large operator	Visit as travelling customer, 2010 Visit to its Gothenburg bus stop and ticket office, 2010	Company website, 2010
	GoByBus	-||-	-	-	Run in practice by a smaller operator	-||-	-||-
	Bus4You	-||-	-	-	-||-	-||-	-||-

Table A.2: Overview of test cases 4–6 and their sub-cases, including data collection

Test case	Sub-case	Location		Characteristics		Sub-case specific data collection	
		In common	Difference	In common	Difference	On site	Remotely
4 Cement[1]	Slite	Sweden	Gotland, Slite	Cement factory run by Cementa	Around 2.0 Mton produced in 2007	-	Environmental report 2007
	Skövde	-||-	Västra Götaland, Skövde	-||-	Around 0.6 Mton produced in 2007	Study visit, 2009	Environmental reports 2006–2007
	Degerhamn	-||-	Kalmar, Degerhamn	-||-	Around 0.3 Mton produced in 2007	-	Environmental report 2007 Production permit law case file 2007
5 Properties management[2]	HSB	Sweden, Gothenburg, Majorna	-	'County governor' housing style Around 100 flats	Run cooperatively	Observation, 10 days, 2003 7 interviews, 2003	Documents, 2003
	Fambo	-||-	-	-||-	Run by the municipality	Observation, 8 days, 2003 12 interviews, 2003	-||-
	Dalavik	-||-	-	'County governor' housing style Around 15 flats	Run by a small company	Observation, 3 days, 2006–2007 2 interviews, 2006	2 interviews via telephone, 2006 Documents, 2006
	Wallenstam	-||-	-	-||-	Run by a large company	Observation, 4 days, 2006–2007 4 interviews, 2006	4 interviews via telephone, 2006 Documents, 2006
6 Road management	Gothenburg	West Sweden	Gothenburg	One procurement unit	-	Interview with its procurement manager, 2010	Procurement website, 2010
	Kungsbacka	-||-	Kungsbacka	-||-	-	-||-	-||-
	Kungälv/ Tjörn	-||-	Ale, Kungälv, Stenungsund, Tjörn	-||-	-	-||-	-||-

(1) Cementa (n. d.)

(2) Brunklaus (2008, pp. 26–27, 2008, Paper III, p. 4, 2009a, p. 123)