A Bumper!?

An Empirical Investigation of the Relationship between the Economy and the Environment

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Abstract

This thesis is concerned with the relationship between the economy and the environment. The relationship is often portrayed as a conflict in public discourse, as if what is good for the economy is bad for the environment and vice versa. The thesis tries to discern if there are common elements in the economy and the environment and how these have eventually become shared. The underlying model assumes that the economy and the environment can be depicted as two separate networks and that elements have to be shared for any relationship to exist.

Of course, in real life, the economy and the environment is interwoven, inseparable and too large to be contained within the pages of a thesis. In order to investigate the relationship, it has thus been necessary to delimit the study to only parts of each network. One of the more important assumptions is that industry is decisive for the production of the economy whereas science is decisive for the production of the environment. Hence, the study should focus on an object that is found in both industry and science. This is done by focusing on aluminium bumpers as the empirical object. Both aluminium and cars have been subject to environmental debates and they are both industries involving large sums of money. In order to aid the production of empirical descriptions, industrial network theory (IMP) and actor-network theory (ANT) have been employed.

The part of the case concerned with the economy describes production of aluminium bumpers for Volvo at Raufoss during the time period 1970 to 2006. The description includes important actors, resources and activities (in IMP terminology) and their development over time. These are explicated as important elements in the economy and presented in a way that facilitates comparison with important elements from the environment.

The part of the case concerned with the environment describes the stabilisation of environmental issues related to aluminium bumpers during the time period from 1970 to 2006. Through a comprehensive study of scientific texts, relations between aluminium bumpers and environmental issues are uncovered. The description includes important actors (in ANT terminology) and their development over time. These are explicated as important elements in the environment and presented in a way that facilitates comparison with important elements from the economy.

The two parts of the case are brought together and compared to reveal if they share elements. A main conclusion is that there are few common elements in the economy and the environment. There are, however, some elements existing in both networks and these have been transferred either directly or

indirectly from one network to the other. The route by which the elements are transferred has consequences for their stabilisation and characteristics upon final arrival. In addition, other elements are needed to aid the transference – in this thesis referred to as *vehicles for translation* – and these have different characteristics and properties.

Acknowledgements

The thesis and I would like to thank several people (and also many non-humans) for stabilising our relationship. First and foremost I thank my supervisors Marianne and Håkan for giving me the possibility to write a PhD thesis and for giving me the freedom to pursue my own interests. You have a perfect mix of capabilities. What a lovely example of resource combination!

All students and faculty involved in the Netlog, Newmark and D Net projects: Thank you for interesting discussions as well as social happenings. Special thanks go to Calle for fruitful (if not really timesaving) development of arguments and to Thomas whom I owe a lot when it comes to believing in my own work. Thank you, Frans, for valuable comments on late drafts of the thesis (and to Lars for at least reading through a chapter). Debbie, you not only deserve gratitude for commenting but for generally aiding in the process (although I had probably finished a year ago if I didn't borrow that book from you). Peter: thanks for your "language laundry" and to Nina for correcting the remaining errors. If there are mistakes left, you cannot be blamed.

(The thesis insists on giving thanks to databases, notebooks, chairs, desks, pencils, trees, computer software, and a whole lot of other non-humans. I hope this parentheses suffices to please the thesis)

All the people from the "real world" (i.e. interviewees and others who have contributed to the case study) deserve standing ovations. I have to mention (doctoral secretary) Bjørn-Anders Hilland in particular. You have been extremely helpful in providing information and to work as a door opener! Ostfold Research deserves a hand for providing me with the opportunity to finish the thesis (and, of course, for giving me a job).

Arne, Michael and Per: Thank you for trying to understand the thesis and giving feedback at times when the thesis was incomprehensible even to me. Other friends and family, I hope to see you more in the near future, if you still remember who I am.

Bjørg; what can I say? Thank you for always bringing me a good balance of resistance and support! I am awfully sorry for all the times when the thesis has made me unable to be the person I want to be for you. Ludvig and Isak, there are still some years until you will understand this text but still thank you for constantly reminding me of what I have been missing when writing the thesis. Now, Let's play!

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For it is only as an aesthetic phenomenon that existence and the world are eternally justified

Friedrich Nietzsche

1. Introduction

When I left my position as a research assistant in a field connected to environmental science to write a PhD thesis at a management school, some of my earlier companions asked me how I could go off and sleep with my enemy. At times I even asked myself the same question. And more.

Do I care about the environment? Do I care about the economy? Do I care about both? Is it possible to care about both simultaneously?

The answer to all four questions is: "Yes, of course." End of story. This thesis ends even before it starts.

Ever since the very early human settlements, the issues of securing a resource base, getting rid of waste and avoiding hazards to human health have been of vital importance for survival and prosperity. These issues are both environmental and economical. The entanglement of the environment and the economy is thus "proven", as is the need to care about both simultaneously… If only the story was that simple.

This thesis is concerned with the relations between the economy and the environment. When it was still in its infancy, such an interest in the connection between the economy and the environment was only prevalent amongst those with a special interest. However, as I write this introductory text now - towards the end of the project – it seems that everybody is concerned about the weather and possible connections between human activities and the deterioration of the natural environment. The need to justify the theme of the thesis decreases proportionally with the dawn of every new day, with newspaper covers screaming at us about melting ice caps, abnormal weather patterns and rising sea levels.

According to the Cambridge dictionary (2005), the economy is: "the system of trade and industry by which the wealth of a country is made and used." The words trade, industry and wealth all have connections to what is referred to as business. Thus, it is fair to say that the economy is intimately connected to business. Business is an activity performed to earn money. Snehota (1990) refers to Webster's dictionary, which states that "business, as a general term, refers to the activities of people who are engaged in the purchase and sale of goods and services for the purpose of making profit," and to Veblen (1904) who states that "the motive of business is pecuniary gain, the method is essentially purchase and sale, the aim and usual outcome is an accumulation of wealth." Business life consists of actors creating wealth for companies and societies by employing resources in internal activities and exchange. The success of business in wealth creation is obvious in today's society.

The wealth produced by the economy is transformed into all sorts of benefits to satisfy our needs. The economy helps to protect people against poverty, starvation and disease, and is inextricably linked to the development of most of the technologies surrounding us.

How could one not care about the economy?

While economy is clearly defined in encyclopaedias, the environment as a term is rather more ambiguous. It may denote that which is exterior to something we focus on, but it is commonly used to refer to the natural environment. In that sense, the environment consists of plants, water bodies, baboons, gases, thunderstorms, whales, rocks, solar rays, guinea pigs, glaciers and thousands of other entities in animate and inanimate categories. The purpose of the environment is open for discussion and probably better suited for a thesis in philosophy or theology than here, but it is fair to say that human life without the environment is pretty unthinkable.

In recent times, we have learnt that the environment is in a delicate balance. The oceans, gases, solar rays – all those elements needed to sustain life – may become threats if we are not careful. Scientists tell us that carbon dioxide, the very gas coming out of our mouths or noses when breathing, may cause serious damage to the heat balance. You can relax a little though: your breathing is part of the natural balance. It is mostly when you burn those fossil fuels created in physical processes over millions of years that you contribute to the enhanced heating effect.

We cannot think the environmental problems away – they are not purely social constructions. However, they are not entering human domains as ready-made knowledge. Intense work is undertaken by an increasing number of environmental scientists to make environmental problems "real" – to translate signs from nature into understandable categories – linking environmental effects to (for instance) the release of specific chemical compounds and thus specific human activities.

How could one not care about the environment?

1.1 The conflict between the economy and the environment – and attempts at solving it

The film "The Day After Tomorrow" presents the devastating effects of global warming in an apocalyptic fashion. The Gulf Stream stops and the world faces a new ice age. The trustworthiness and the quality of the film can obviously be discussed. However, what puzzled me was a scene at the beginning of the film. The hero of the day, the devoted scientist, is presenting his figures about a more rapid change in the climate than had been predicted earlier (although not as rapid as it eventually turns out to be in the film) to a group of politicians, urging them to implement measures to limit emissions of climate gases. His proposals fall on deaf ears, as the politicians claim the economy is much too fragile to be tampered with just because of one man's beliefs. And I did not react. I believed the scene could actually have happened. I was completely puzzled by not being puzzled. That the stereotype of the economist not caring enough about the environment could be so taken-for-granted.

Almost every day, when listening to a politician or a scientist or a businessman or reading a newspaper, the relationship between the economy and the environment is presented as carrying an inherent conflict. As if what is good for the economy is bad for the environment and vice versa. Spokespersons from each side scream about the threats posed by the other: the environment (or rather its spokespersons) accuses the economy of ruining the environment, while the economy (or rather its spokespersons) accuses the environment of being filled with doomsday prophets creating unnecessary constraints on the economy.

Figure 1-1 provides a cartoon view of this divide, showing how the two sides look upon each other.

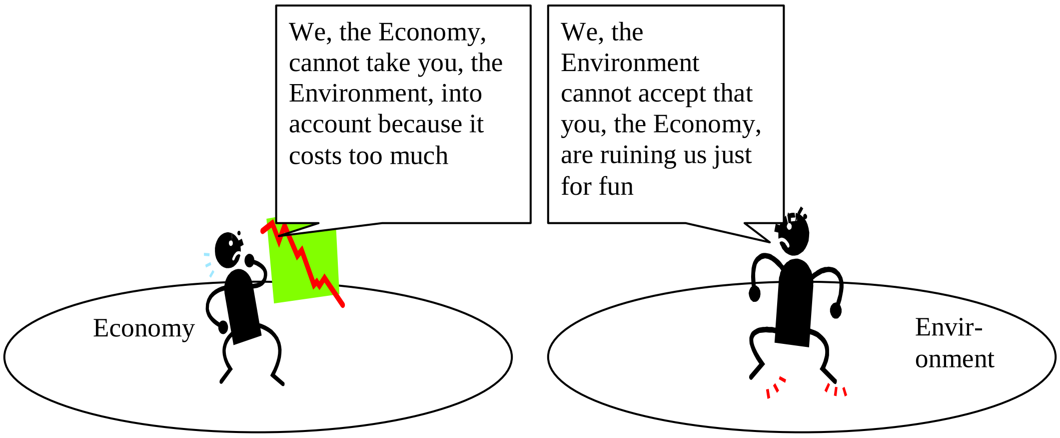

Figure 1-1 A cartoon view of the conflict between the economy and the environment

Obviously, the division is not total for then the spokespersons would not care about each other. Obviously, the environment is just as much a part of the economy as the economy is of the environment. But *how*? That is the issue of this thesis. Where are the connections between the environment and the economy? And what might they look like?

From discussions in the public domain, it is easy to get the impression that the environment is packed with doomsdays prophets, while the economy is an assembly of headless hedonists. However, the latter have created strategies to show us all how we could be better off. Why is the economy all about a prosperous future, while the environment is about doomsday? There is also anxiety in the economy – costs are getting too high, we could go bankrupt next year; likewise, there is also joy in the environment itself – the feeling of every individual as part of nature, the sound of birdsong one day in early Spring. Some of the characteristics of the environment and the economy are shown in Table 1-1.

Table 1-1 Stereotypical characteristics of the environment and the economy

	Environment	**Economy**
Aim	Sustained human existence?	Profit
Means	Scientific proofs and activism	Efficient production
Modus Operandi	'Hot' emotions	'Cold' rationality
Future Outlook	Catastrophic	Bright
Personality	Naïve	Cynical

The reason why an image of a conflict or divide between the environment and the economy is sustained (and maybe increasing) is mainly connected to the high level of exclusivity that has crept into society. Sciences, professions and newspapers are more and more specialised (e.g. Grant 1996; Ravitch & Viteritti 2001; Szulanski 1996).[1] Communication between people in what used to be the same, or at least adjacent, fields is hampered by the introduction of 'tribal' languages, which makes it difficult to understand even seemingly closely related subjects.

This is not to say that no attempts have been made to 'close the gap' between the economy and the environment. The words 'green' and 'environmental' are being attached to almost every scientific subject, including subsets of the economic sciences. Examples include 'green marketing' (e.g. Grant 2008), 'green purchasing' (e.g. Min & Galle 1997), 'green logistics' (e.g. Rodrigue et al 2001) and 'environmental economics' (e.g. Hanley et al 2001). None of the specifics of any of these attempts are treated within this thesis, unless they show up explicitly in the environment or the economy. In general, I would claim that all these attempts fail to take both the economy and the environment seriously at the same time. The environment is translated into quasi-economic objects, without the power to convince the majority of people in either domain that they are relevant or worthy of attention.

Even fewer attempts are made at introducing economic thinking into environmental studies, for reasons that may become clearer during the course of this thesis. However, industrial ecology might arguably be referred to as an exception (see for instance Ehrenfeld 2000).

[1] This may well be far from new, as I do remember having read a passage in Weber from the beginning of the 20th century stating something like "anyone trying to be an

1.2 A preliminary research question and its delimitations

This is all quite confusing and one of the aims of this thesis is to clarify some of the relations between the economy and the environment. A first general formulation of the research question guiding this study becomes:

How does the environment affect the economy and vice versa?

The word 'how' in the question points both to the process of affecting and also the outcome(s) of the affecting process. The question itself is clearly too "big" to be answered, at least by one thesis. It needs refinement, using premises and assumptions for giving an answer.

First of all, a provisional delimitation of the economy and the environment must be made. Such a boundary-setting activity could for instance take the mass media as its starting point. The thesis could have compared images of the economy and the environment as produced in newspapers and on TV. However, although I believe the mass media to be important in creating and sustaining some of the content of the two domains under scrutiny, there are other domains more instrumental in the constant production and reproduction of the environment and the economy, especially science and industry. A crucial assumption underlying the thesis is that economy is largely a product of industry and environment is largely a product of science.

Secondly, the focus is on the empirical relationship between the two domains, that is, how the economy as produced in industry is related in practice to the environment as produced in science. Even though a study of theories concerned with connecting and disconnecting the domains could have been interesting in itself, the focus here is on relations between the economy and the environment in practice rather than in theory.

Thirdly, following on from the last point, the empirical material for the thesis needs to be related to an empirical domain where traces of both the economy and the environment can be found. That is, the object of study should be found both in industry and in sciences related to the environment. Hence, the point of departure is an aluminium bumper beam.

Wait a minute!

What is a bumper beam? And why study such an aluminium bumper beam?

A bumper beam is a car component, situated between the bumper and the chassis on a car and shown in Figure 1-2.

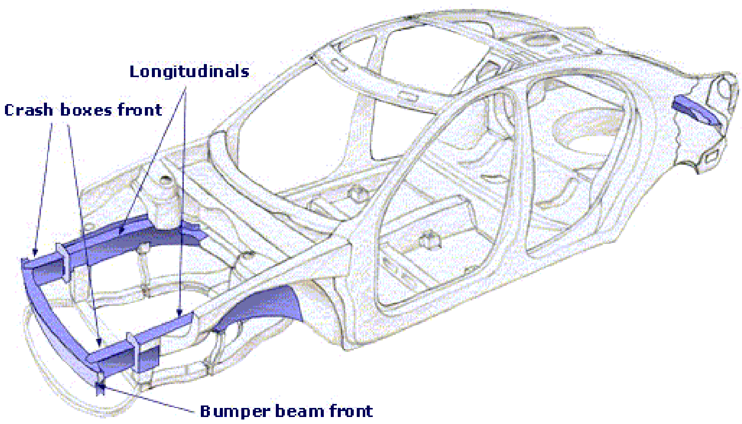

Figure 1-2 The placement of the bumper beam in the car

Its main function is to protect the car in medium-speed impacts.[2] However, the definition of the bumper beam will be developed as it becomes clearer how it relates to the environment and the economy.[3] More important than its functional characteristics (for this thesis, at least) is its presence in both the economy and the environment. The bumper beam obviously has economic properties, as it is an object of exchange between companies. Environmental properties are also likely to be present, as it contains material extracted from the earth and its production leads to the release of emissions.

1.3 A first refinement: from domains to networks

An important aspect related to the assumptions has to do with what is meant by domains. Five domains have already been mentioned – economy, environment, mass media, industry and science – and it has been claimed that there are relationships between them.

Of course, the 'real' world has no clearly separated domains and the distinction I have made between the economy and the environment is not true *per se*. It is not given by an act of God. However, it is not entirely created in my head either. People and technologies are constantly involved in refining domains and in bringing domains together. For instance, the "economy" label is often given to institutions, newspapers, professors,

[2] The bumper beam is not designed to protect the people in the car specifically but rather the engine and other functional parts.

[3] We will also learn that what is now referred to as a bumper beam was formerly called a bumper. These denotations will be used interchangeably according to the time in history.

politicians and others to demarcate them from everything else. This means that parts of the various domains (e.g. science or mass media) are more involved in the economy domain than in "their own" domains.

The thesis is thus based on a model of the world as composed of different domains as shown in Figure 1-3.

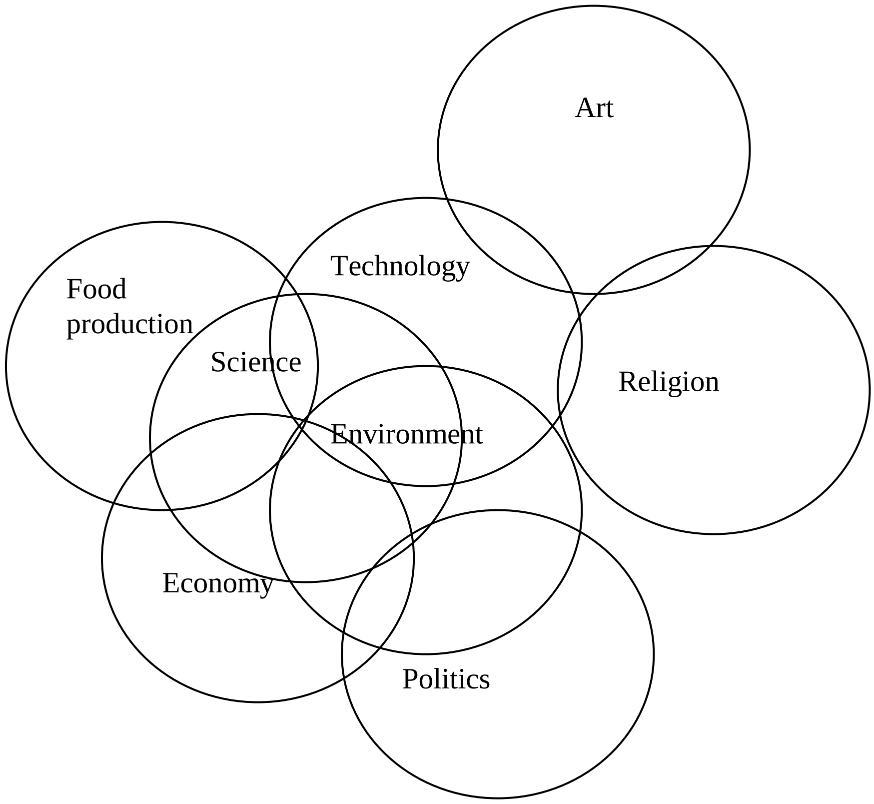

Figure 1-3 The world as a collection of domains

The representation in the diagram is of course false, as it tries to show a range of connections in just two dimensions. All of the domains are probably connected to each other, although the links between some may be rather weak. At least one more dimension would be needed to capture all the intricate connections, as there are several places where more than two meet and the meetings may not happen instantaneously, that is, the connections may be stretched out in time. A domain may be seen as having its own operating procedures and a language created to distinguish them from others. Such a definition may give the impression that the domains only consist of human beings and their activities. On the contrary, the theoretical model for the thesis rests on the assumption that each domain is heavily influenced by entities other than human beings (e.g. Håkansson & Snehota 1995; Latour 1999b).

Within a domain, there is constant work to reproduce, confine or expand the content, although it does not mean that each domain is a system with a central brain. For instance a written law has a different meaning depending on which domain is used to explain it. The political domain is seen as the place where the law is produced, although its final formulation and execution often occur in the legal domain and its influence may be felt in the economy domain, while the environment may be the domain that the law protects.

Following on from this, domains must at least be three-dimensional and it is questionable if allegories of a domain or a sphere are at all useful. The mere act of considering the potential content of a domain reveals that they are so interwoven that any specific element can belong to a number of domains. Hence, both the label of a single element and the composition of the larger 'structure' are subject to fluctuation.

The topography of the domains can therefore hardly be shaped as circles, spheres or any other simple geometric figure. They seem to have more of a molecular structure, one of nodes connected by bonds. To escape the chemical associations and rather link up with a word more frequently used in a range of social sciences, networks can be a more fruitful allegory (e.g. Håkansson & Snehota 1989; Latour 1997; 1999a; Law 1992). Thus, from this point on I will refrain from the use of words like 'domain' or 'sphere', and instead stick to the word 'network'. A representation of society as seen as different overriding networks is shown below.

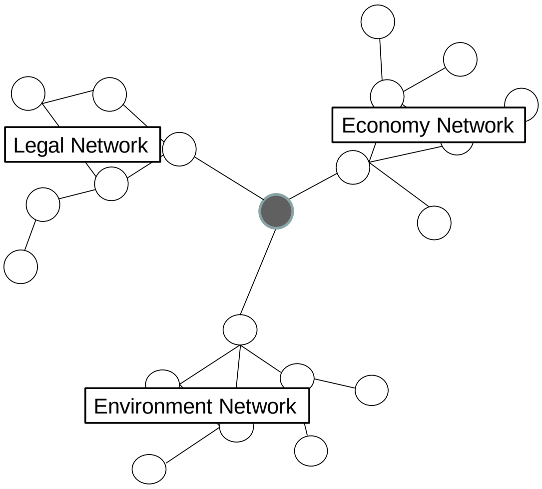

Figure 1-4 Society as networks. For the sake of illustration, I have let all the networks share one element.

Recognising that most entities encountered in society consist of a heterogeneous mix of elements from a variety of such overriding networks, the whole idea of operating with such larger 'structures' may be contested. However, as shown for the economy and the environment, a lot of work has been done to refine each of them, to create separate languages and ways to operate. Still, many of them rely heavily on other networks for their own existence.

It is assumed that the production of the environment network is largely down to science; hence, elements of the science network are granting credibility to the environment network. Although this network is certainly composed of other actors – NGOs, a beautiful waterfall or a newspaper column – its expansion and legitimacy can largely be considered to be the result of science.

The economy network, on the other hand, is mostly produced in the industry network. It means that other actors – the finance professor, a retail outlet or credit cards – are not granted the same importance in confining and defining the economy network.[4]

[4] Although such a statement might provoke economists, i.e. scientists within economic sciences, I do not assume the existence of economics to be all that important to the content of the economy, as economy is often produced before economics and the latter is a result of the former rather than the opposite.

Understanding how industry operates thus increases knowledge of the economy, as understanding the mechanisms of science increases the understanding of why the environment looks like it does.

1.4 A second refinement: why choose a bumper beam?

Car manufacturing has been honoured for developing both mass production and later lean production and has thereby showed awareness in relation to production efficiency and economic issues (Womack et al 1990). On the other hand, cars in general, and especially the automotive industry, have been targets of criticism from environmental organisations for decades (Carbusters 2003).

The bumper beam is not as clearly linked to the environment as, for instance, the choice of fuels in cars, but knowing that it can be made of different materials – with steel, aluminium and plastic composites being used most often – makes potential environmental debates visible.

Thus, tracing the bumper beam's existence in the economy and the environment, respectively, should provide knowledge about the relationship between the two societal networks.

1.5 A third refinement: from economy to Economy* and from environment to Environment*

I will now introduce two proxy variables, as it is hard to clearly define the economy and environment networks and because whatever empirical area is chosen, it can never capture the whole of what economy or environment is. These are called Economy* and Environment* and will be filled with content during the empirical parts of the thesis.

The proxy variables are related to set theory. In primary school, we were taught that all fire engines are red vehicles (at least in Norway they are), but not all red vehicles are fire engines. In this thesis, Environment* is to the environment network what fire engines are to the category of red vehicles. Environment* is thus the portion of the environment network created by science that is related to aluminium bumper beams. Similarly, Economy* is the part of the economy network produced by industry in relation to aluminium bumper beams. This is not to say that the elements covered in the thesis are *only* related to bumper beams. Rather the contrary, as I do not believe bumper beams to be a driving force either for the economy or for the environment, most elements covered within this book are probably produced for other purposes. And that is a strength rather than a weakness. This thesis is concerned with the relationship between the economy and the environment, not the specifics of bumper beams, although such specifics are used to shed light on the aforementioned relationship.

Neither the Environment* nor the Economy* will be predefined categories. The assumption from the outset is, however, that the Environment* is predominantly produced by scientists and the Economy* similarly by industrial companies. This has consequences in terms of where to seek information about the networks and what information to seek. I will not decide whether the Environment* is about green trees, species at risk from extinction, emissions of gases, noise or traffic injuries. Instead it is used as a collective category for all verbal and material arguments related to life and health. If I seem too preoccupied with the effects of nitrogen oxides or too little interested in disposal of nuclear waste, it is because the pressing issues are defined by the empirical study. In much the same way, the Economy* will not be treated as an unambiguous category, but will be defined by the case where such issues as growth or survival of companies are present. Thus the Economy* can be just as much about securing local employment as about share dividends and profit, about efficient logistics processes just as much as about the marketing of products. Common to the descriptions of the Environment* and the Economy* is that both will be based on relations: relations between actions, materiality and human beings (Håkansson & Snehota 1995; Håkansson & Waluszewski 2002; Latour 1987; Latour & Woolgar 1979).

1.6 More specific research questions

From the first refinement, the preliminary research question stated in Chapter 1.2 can be reformulated as follows:

How does the economy network affect the environment network, and vice versa?

The transformation from domains to networks also influences the way to understand what "affect" means and how effects can be achieved. In order for two networks to affect each other, an element (node) must be shared so that it exists in both networks simultaneously. Thus, the research question can be divided into two more specific questions:

1. *What elements are common in the economy network and the environment network?* and
2. *How did these elements become common*?

These questions require thorough knowledge of both the elements included in both networks and the mechanisms with which each of the networks are produced and reproduced. As doing this for the entire economy and the entire environment would be a hopeless task, the last two refinements narrow the areas that must be searched and researched. The first of the questions posed above can thus be rephrased:

1. *What elements are shared in the Economy* and the Environment** and still
2. *How did these elements become shared*?

The thesis will thus map out the elements of the Economy* and the Environment*, explain their production and provide descriptions of how some elements have become shared. These findings can be used to increase understanding of the relationship between the economy and the environment. Such knowledge can be useful for business managers who want to be more aligned with environmental issues, environmentalists who want to get a grasp on why it may be difficult to integrate environmental issues into the economy, politicians who wants to create a framework for industrial production and development with a concern for the environment and, last but not least, scientists who want to take the economy and/or the environment into account.

1.7 Outline of the thesis / roadmap

Chapter 2 presents the underlying ideas about the collection, treatment and presentation of empirical material to answer the research questions. The "theories" [5] underlying the study are displayed and discussed and issues pertaining to worldviews and the reliability of the study are addressed.

Chapter 3 contains a presentation of the Economy*, that is the part of the aluminium bumper beam case confined to industry. The bumpers and bumper beams produced in the relationship between the car manufacturer Volvo and their supplier at Raufoss between 1970 and 2006 are used to emphasise the production of Economy*. The elements that make up or have made up the Economy* are presented. These will be used to discuss the relationship between the economy and the environment.

Chapter 4 is a presentation of the Environment*, i.e. the part of the aluminium bumper beam case confined to science. Environmental issues

[5] The reason for the use of inverted commas will become clear during the presentation.

related to bumpers and bumper beams are traced through scientific articles between 1970 and 2006 to emphasise the production of Environment*. The elements that make up or have made up the Environment* are presented. These will be used to discuss the relationship between the economy and the environment.

Chapter 5 presents elements that are common to the Economy* and the Environment*, explaining how the elements travel from one network to the other. The mediators – the vehicles of translation – that make it possible for elements to travel from one network to the other are displayed and some of their features discussed.

Chapter 6 concludes the thesis. The chapter includes a presentation of the main findings from the study, a discussion of the case in relation to the findings and intentions of the study, possible contributions to theories and practices, and recommendations for further studies.

2. Research designing

This chapter will outline the empirical and analytical strategies for capturing the relationship of the Economy* and the Environment* as they are sketched in the introductory chapter of the thesis. I will focus particularly on how the strategies are implemented, that is, how empirical material is collected and organised. There is no natural order in which to present the research strategy, as every written account will give a more ordered presentation of the process than how it is undertaken in real life. The ideal presentation would perhaps be to have the document as a web page where the reader could click back and forth among hyperlinks, with the document itself having neither a beginning nor an end. This chapter does, however, conceal the chaotic process of iterations between 'methods', strategies, empirical sites and conceptual thinking, as well as endless pondering on the true nature of research and the world and if there is such a thing as a true nature. It starts with a short presentation of the empirical domain before briefly presenting the "theories" applied to structured data gathering and analysis and discussing why there are two of them. Then follows a short presentation of the basic worldview underpinning the study. Thereafter the specifics of how data is gathered and organised is presented, and the chapter concludes with a discussion of how explanations are made and how reliability can be evaluated.

2.1 Selecting empirical material

With the relation between Environment* and Economy* as the starting point, I was determined to find an empirical area where both networks should be present, in line with what Eckstein (1975) calls a *most likely case*. The automotive industry seemed like an obvious choice. However, the aluminium bumper beam was not only chosen for its connection to the automotive industry. In addition to a special interest in aluminium as a material, I also knew of a Norwegian producer of such components, namely Hydro, and I knew Volvo to be one of their important customers.

During my years of working with environmental analysis before entering a PhD program, I learnt that both Volvo and Hydro have been instrumental in using and even developing environmental assessment tools. A quick glance at either Volvo's or Hydro's homepage will reveal that they are both interested in incorporating environmental qualifications into their activities. They seem more than happy to be able to present and document their ongoing efforts relating to environmental performance and environmental improvement of processes. Volvo was the first company in the automotive industry to present an environmental policy back in 1972 (Volvo 2003). They have been involved in numerous projects on business and sustainability. I knew both Volvo and Hydro to be successful companies. They have large revenues, a large number of employees and have stayed in business for a long period of time. And finally, they feature some characteristics that make them easier to trace, as indicated below.

Access and availability

Large industrial organisations are often hard to penetrate and gaining access to the relevant people can be a cumbersome task. The possibility of finding interviewees is one of the main reasons why I chose Hydro. In my former job, I had participated in a project group with a Hydro employee from the Environmental Research Department. He knew who to talk to and his name worked as a "door-opener" for gaining access to other people in the organisation. These people were able to help me with the specifics of the case, provide information about the case and refer me to other people within both Hydro and Volvo who were involved in the production or development of bumper beams.

Geographical proximity

The premises for bumper beam production and car assembly are, respectively, only a two-hour and a four-hour train ride away from my office. Hydro Automotive has an office in Oslo, as well as one in Raufoss (where production takes place). Volvo's office is located next to the assembly plant in Torslanda just outside Gothenburg. This proximity made it more convenient, both financially and time-wise, to visit these companies' sites, rather than those of any other producers involved in the car industry.

Language

The interviews and many of the documents have been in Nordic languages, i.e. Norwegian and Swedish. It would have been harder to understand or even get hold of a lot of this information without knowledge of these languages. Obviously, it creates a problem at the "other end", where case information must be translated into English and where information may disappear or get distorted. However, I believe this to be a lesser barrier than having to rely only on those sources with an accessible language.

Social proximity

Together with a common language, the sharing of common cultural references makes interviews easier to perform. The requirement of understanding expressions, both technical and social, is thus made easier. Several of the interviewees even attended the same university that I did, which has contributed positively to the atmosphere of the interview on more than one occasion.

2.2 Searching for the Economy* and the Environment* (empirical and analytical theorising)

Having selected what to study and justified the reasons for the selection, the task of identifying how to study it is next. The bumper beam is not interesting per se, but is used to exemplify relations between the economy and the environment.

Whatever the Economy* and the Environment* turn out to be, I do not believe there are any theories that are currently able to capture any of them fully, or at least not the relationship between them, particularly if we take 'theory' to mean a ready-made scientific explanation where data can be inserted to check if the explanation holds or not. I do, however, believe that a random approach without any guiding principles would be just as, or even more, misleading. I have therefore chosen two scientific approaches, often referred to as theories although both are resistant to be termed so, to structure the empirical and analytical work. These two are the IMP network approach (IMP) and the actor-network theory (ANT), both which are presented below. The idea is to apply IMP to sort out the Economy* and ANT to do the same job with the Environment*. Concepts from each approach will be used to aid data gathering, organisation of empirical data and analysis of data. It may be a stupid idea; one fit for raising questions such as: "Why use two approaches?", "Wouldn't one be enough?" and "Are they compatible for use in the same study?" I will try to answer these questions, even though final judgement will have to wait until the study has been conducted and evaluated. Let us first see what the approaches have to say.

2.2.1 The IMP network approach

In order to carry out an empirical study of the Economy*, I needed to find an approach to study economy that was positive towards and allowed for empirical enquiries. The IMP network approach (IMP) has grown out of empirical studies of business and should therefore provide a good starting point.[6] Such a view is in line with what McLoughlin and Horan (2002) write:

[6] IMP is also referred to as the industrial network approach, industrial network theory, or the Markets-as-Networks approach

> "The mainstream view is that any gap between science and practice was due to the irrationality of managers that must be curbed and brought into line with the prevailing theory. For network researchers, on the other hand, the relationship was the opposite. A gap between science and practice meant a deficit of theoretical knowledge that must be met" (p. 540).

In 1976, a group of young enthusiastic researchers from several European countries formed the Industrial Marketing and Purchasing (IMP) group. According to Wilkinson (2001), "they were dissatisfied with the dominant marketing paradigm of the time, which focused on consumer goods and adopted a stimulus response, arms-length approach to the customer with seller as the active party." Inspired by empirical findings of stable relationships between companies, they started a study of such relationships between purchasing and selling firms from France, Italy, Sweden, West Germany and the UK. The results were published in the first IMP study (Håkansson 1982), where an interaction model was developed. During the 1980s, the scope was widened to include companies outside the focal relationships and the interaction model was supplemented with a network model (Håkansson 1987). The research stream has developed towards an alternative conceptualisation of the market. An alternative to the 'classical' market model, that is:

> "According to the markets-as-networks approach, not only is exchange interactive but individual market transactions take place within dynamic exchange relationships between parties who are not anonymous…[The] *market* is considered as networks of multidimensional, dynamic exchange relationships between economic actors, who control resources and carry out activities. In these exchange relationships social relations are developed, knowledge is exchanged and developed, technical changes and adjustments, sometimes of an innovative nature, take place, logistical activities are coordinated." (Mattson 2003:6-7, emphasis in original)

We have already come to realise that IMP proposes an alternative approach to understand business life. Ford and Håkansson (2006b) discuss two challenges in linking IMP to prevailing ideas. The first is related to the view "that the structure of the business world is comprised of companies that are more or less independent of each other and which are each able to build and execute their own strategy." The second to the view "that the process of business consists of the independent actions of individual companies, directed towards a generalised group of 'customers', 'suppliers' or 'competitors' and intended to have an effect on that group as a whole."

The way the challenges are phrased make them almost appear as theoretically driven, but it is emphasised that interdependence and network properties are evolving features of business life:

> "Increasing technological intensity and the associated pressure of cost have led companies to become more specialized and hence more inter-dependent with each other. This increasing interdependence has led to ever-more complex interactions, facilitated by improved communications between companies with an ever wider variety of resources and ways of operating" (Ibid:8).

These empirical observations are specified by Håkansson (2006):

> "[An] indicator of a change in the business world is the use of new managerial tools or sets of advice. There are a number of such tools having network attributes. There are general methods such as JIT (just-in-time) where companies are advised, through closer relationships, to take out costly time in production chains and TBM (time-based management) where not just production but also development schedules involving several companies should be adapted. In addition, there is TQC (total quality control) where the issue is to increase the total quality by applying the same standard in all production stages, again involving several companies producing a product. There is also the development of much more specific managerial tools, especially within marketing and purchasing, including customer relationship management, supply chain models and key account management, which all are examples of new and closer ways (thicker interaction) to relate to counterparts" (pp. 146-147)

In order to make sense of these empirical observations, some of the most important concepts and assumptions will now be presented. These are relationships, interaction, heterogeneous resources and networks. Finally, IMP's relation to the Economy* and to the practical accomplishment of the thesis is outlined.

Relationships and Interaction

IMP was based on the existence of business relationships and was for a long time devoted to exploring the content of relationships and the mechanisms involved in their formation and continuation. The starting point is *not* that relationships are intrinsically good. IMP is a descriptive rather than a normative approach. In fact, emphasis is placed on how relationships provide both possibilities and constraints for the involved parties.

> "The interdependencies in an actor's existing relationships simultaneously empower and constrain its ability to achieve change and

> growth. Thus an actor's dependence on the resources and the problems of others increases its freedom to invest its own resources in more productive areas within that relationship or elsewhere and provide the basis for it to develop in new directions. But at the same time, an actor's existing relationships restrict its freedom to act in the directions of its own choice and require it to invest resources in interaction within its existing relationships. A key aspect of business interaction is the building, managing and exploitation of interdependencies over time" (Ford & Håkansson 2006a).

Håkansson (2006) gives more specific examples on what possible benefits may be:

> "…The stability in terms of counterparts can be used as a means of framing and creating development in technical or other aspects. Relationships become the framework for joint development of technologies and other types of new solutions. The dynamic role is significant, and important relationships often include product and production process developments. One aim is to increase efficiency in production, handling, or transporting the products or the design of the product or production system" (p. 153)

Relationships are all-encompassing, in that they steer the directions of the involved actors and not only those human individuals directly related from the two organisations. This is also connected to the fact that any single actor cannot choose how the relationship will evolve.

> "Relationships aren't just an issue for marketing or purchasing. Those areas of corporate activity that are traditionally viewed as "internal" to a company and as solely its responsibility are not really internal. And they are certainly not wholly controllable by the company itself. For example, a company's human resources, operations, finance and research and development are all affected by and affect the company's relationships. In fact, it is equally valid to say that the nature of a company is defined by its relationships, as it is to say that the company itself defines its relationships" (Ford & Håkansson 2006b:9-10).

Instead, relationships evolve through interaction.

> "Interaction emphasises that the processes that occur between organisations are beyond the complete control of any individual actor. Interaction is not the outcome of the factors that drive a single action by a single actor. Instead, it is a process in which the effects of any action are affected by how that action is perceived and reacted to by the counterparts. This reaction then triggers re-reactions from the initiating actor and so on" (Ford & Håkansson 2006b:4).

Which further means that:

> "Putting interaction at the centre makes it impossible to make sense of what happens between business companies by looking at just one of them. The direction of a business relationship is outside the control of a single company. Neither of the companies involved owns, directs or manages it. A relationship has an "interactive existence" beyond that of the participants" (Ford & Håkansson 2006a).

These citations show the relative (or relational character) of relationships. But as yet, there has been no explanation of what interaction actually consists of. Ford and Håkansson (2006a) state that:

> "Interaction isn't just a set of conversations that lead to some abstract agreement. Nor is it something that takes place alongside "real" business. Interaction has a substantial and physical form. Interaction does include interpersonal communication. But companies also interact through delivery of physical products and services, information and payments and also through more one-sided observations. All interaction has specific meanings for those involved and for those affected by it. All subsequent interaction will be based on these interpretations of that meaning by all of those who are affected by it. All interaction is concerned with the physical world. The economic effects of interaction appear in the physical world and the outcomes of interaction are within the constraints of that physical world. Interaction can be seen as the interplay between different actors, but also as the interplay between the abstract ideas of those actors and the physical constraints that surround them. In this way, interaction provides the link between technology and economy" (pp. 8-9).

Interaction is thus physical, but still connected to the interpretations of the actors. An important point is the last one made in the citation, 'the link between technology and economy'. For relationships to make sense, there must be a chance of increased revenues or decreased costs being achieved as the result of development through interaction. This brings us to one of the important assumptions in IMP: unlike most mainstream economic approaches, resources are viewed as heterogeneous.

Resources are heterogeneous

> "One of the critical basic assumptions in market theory is the need to assume that resources are homogeneous from an economic point of view. As soon as the value of resources is not a given but can be improved, for example, by finding a better way to combine them with each other, then the market form cannot work properly… However, homogeneity and heterogeneity can also be related to change. A

> homogeneous resource is given – it is, from an economic point of view, frozen and therefore cannot be developed. This is not the case for a heterogeneous resource. Such a resource can always be improved by finding new and better ways to combine it with other resources" (Håkansson 2006:161-162).

This is one of the most important points in IMP and one that I find appealing. The specifics of the technologies employed and the real content of the exchange matters. IMP is not ignorant to whether the interaction involves development of a car or exchange of bananas.

The definition of a resource, as given by Snehota (1990), is:

> "A resource is an element, material or immaterial, that can be used for some purpose. It is the purpose that makes an element become a resource and no element, material or not, is a resource without a known purpose" (p. 173).

The definition is similar to the one in mainstream economics; it is thus the element of whether the resource has a set value that is under scrutiny. IMP has been inspired by the resource approach laid out by Penrose (1959). Returning to Snehota (1990), he emphasises how the resources are important elements of the business interaction:

> "The notion of costs is related to use of resources. The value of resources reflects their contribution to the achievement of the purpose. The relation between resources, costs and achievements of a purpose is somewhat complex. The value of resources is given by the use of them, they have no intrinsic value; it is the use, or capability to use resources that confers resources their value. Resources become valuable as a support to activities undertaken for a certain purpose, a mere possession does not make them valuable" (188).

The resource layer has been emphasised by several researchers, especially in the Nordic countries. Both the assumption of heterogeneity of resources and the outcomes of resource heterogeneity have been scrutinised (e.g. Holmen 2001; Håkansson & Waluszewski 2002; Jahre et al 2006; Wedin 2001).

Emergent networks

> "There is no single, objective network. There is no "correct" or complete description of it. It is not the company's network. No company owns it. No company manages it, although they all try to manage in it. No company is the hub of the network. It has no "centre", although

> many companies may believe that they are at the centre" (Ford et al 2004:4).

This rather harsh statement summarises IMP's industrial network approach. Networks are neither something companies set up nor "a priori structures to be imposed on organizations" (McLoughlin & Horan 2002:537). It follows that the processes involved in developing and maintaining networks, or 'networking' in the words of Ford et al (2004):

> "isn't something carried out by a single company that 'manages its network' or something that is done 'to' some other companies. All companies are networking by suggesting, requesting, requiring, performing and adapting activities, simultaneously. The outcome is the result of *all* those interactions!" (p. 7, emphasis in original).

Networks are complicated material and attempts at understanding them have been developed and refined through the so-called network model (see for instance Håkansson 1987; Håkansson & Snehota 1995). The network model includes three layers of substance in business: activities, resources and actors (hence, it is often referred to as the ARA model). Each of these layers is seen as dependent on the other two.

> "Actors are defined as those who perform activities and/or control resources. In activities actors use certain resources to change other resources in various ways. Resources are means used by actors when they perform activities. Through these circular definitions a network of actors, a network of activities and a network of resources are related to each other" (Håkansson & Johanson 1993).

Figure 2-1 shows the interconnection between the three layers.

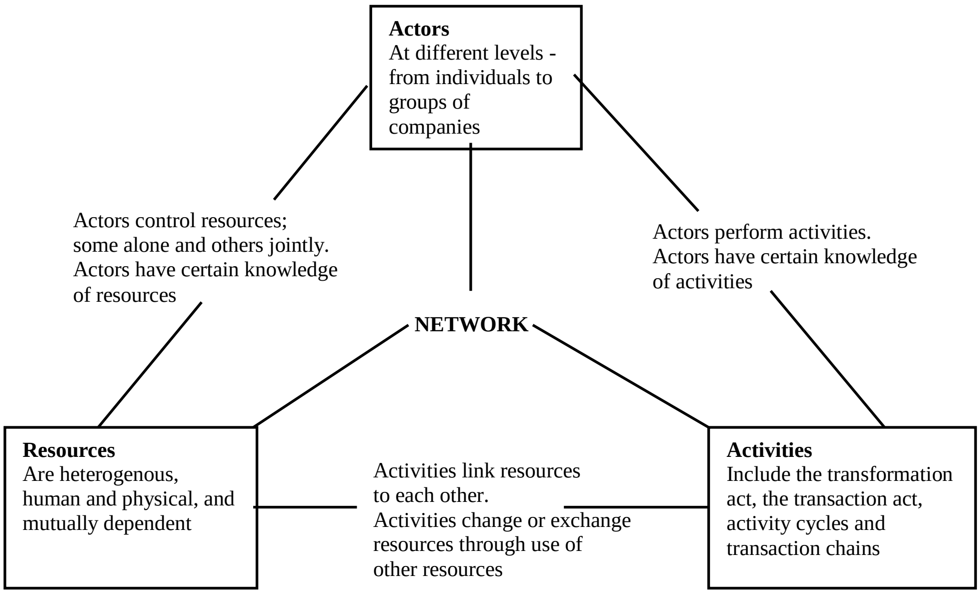

Figure 2-1 The Network Model. (Håkansson 1987)

1. A business relationship *links activities*. This layer is especially related to *productivity* and *efficiency.*
2. A business relationship *ties resources*. This layer is especially related to *innovation* and *technological development.*
3. A business relationship *bonds actors*. This layer is especially related to *identity* and *power structures.*

One of the reasons to include all three layers was that each of them is a typical feature of any economic model. The difference in IMP related to the others is connected to the emphasis placed on each of the layers. Many business models are preoccupied with actors (for instance, within strategy as discussed in Baraldi et al 2006) or activities (for instance, within logistics as discussed in Jahre et al 2006). The ARA model does not grant any of them a special status; they are seen as equally important in the constitution of the others and of the total network. This equality may, however, give the impression that IMP 'favours' the resource layer only because the resource layer is underdeveloped in many other economic theories.

To develop the model of the three layers, the researchers in IMP have borrowed insights from or been influenced by several different theories, such as history of technology (Freeman & Perez 1988; Hughes 1984), social network theory (Dosi 1997; Granovetter 1973), social exchange theory (Emerson 1976), sense making (Weick 1995) and transaction cost theory (Williamson 1975).

The three layers exist on three levels: the company level, the relationship level and the network level. The layers and levels can thus be inserted into a 3X3 matrix as shown in Figure 2-2.

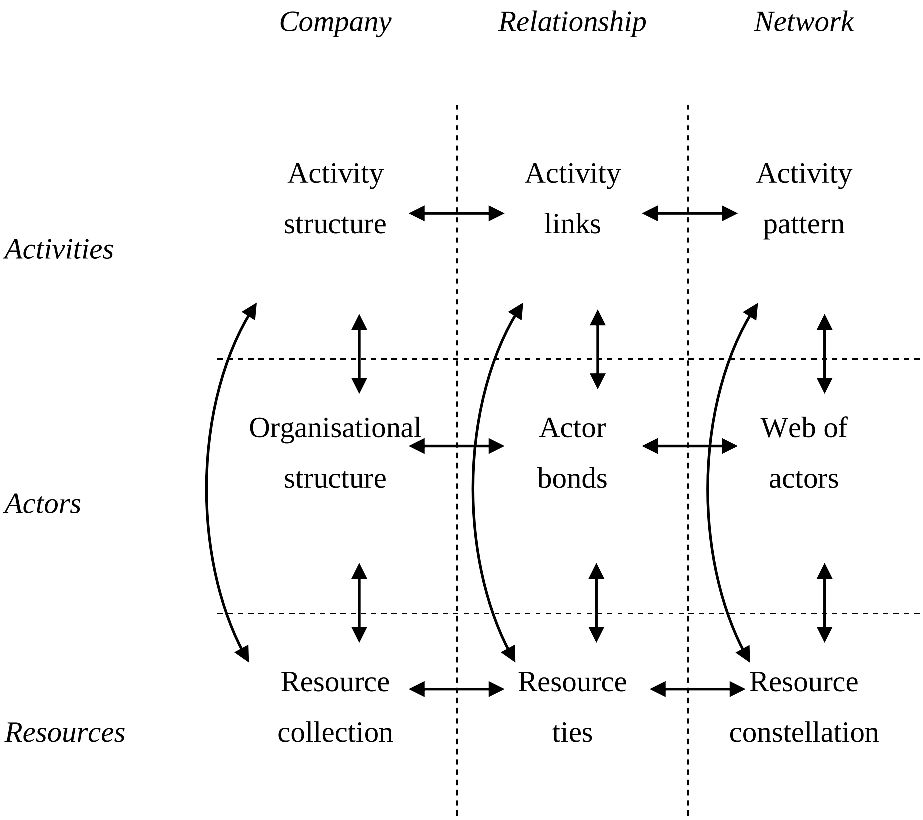

Figure 2-2 Scheme of analysis of development effects of business relationships (Håkansson & Snehota 1995).

The scheme of analysis shows interconnection between the layers and between the levels.

More specific models have been proposed for the resource layer, the so-called 4R-model (e.g. Håkansson & Waluszewski 2002; von Corswant 2003; Wedin 2001) and for the activity layer (Dubois 1994). These models are employed for the specific purposes described in relation to Figure 2-1.

IMP, industry and the Economy*

Although the model of an economy based on relationships is quite different from a model based on atomistic exchange episodes, IMP does not oppose the general view of the function of the economy for companies. In fact, Snehota (1990) states a 'classical' view on how economy functions to conclude that this presupposes the reality of relationships:

> "Market exchange opportunities arise when there is a pair of market participants who attribute different values to goods, to a bundle of benefits, to a potential object of exchange (product or service). Market exchange opportunities can be exploited and gain can be achieved through market exchange transactions by which a redistribution of property rights is achieved.
> It then seems intuitively easy to accept the notion that opportunities for gain in business are linked to privileged knowledge about the existence and alternative use of resources and about the potential exchange parties" (p. 36).

IMP thus does not question the profit-seeking nature of business, but claims that profit-seeking goes through mechanisms other than faceless transactions. This again means that the mode of increasing profit is changed, making the output immeasurable in standard economic terms as it is related to a network rather than a single actor.

The network model, together with several studies influenced by it, forms the basis for collecting and writing the empirical material related to the economic aspects of the bumper beam. All three layers are seen as important in the formation of the Economy*.

2.2.2 Actor-Network Theory

First comes a warning, and it comes in the words of John Law (1999):

> "The success of actor-network theory [ANT] has led to its dissolution. From signal to noise. But this shift, its diasporic character, also reveals its strength. For if it is now time to abandon stories that tell of straining towards the centre then this is because doing so has helped to perform alternative narrative strategies. Strategies that are not always narratives. Narratives that are not necessarily strategic. Alternatives that are about the making of objects and subjects. That are ontological. Alternatives that have generated the possibility of an ontological politics where object may be made and remade, remade in different images" (p.10).

The warning is not foremost that actor-network theory is dissolved and therefore not applicable anymore, but rather that exploring the world of actor-network theory, or the sociology of translation, can take you to places where the words employed are quite different from those you normally encounter in sciences. This immediately leads us back to the continuation of the passage in Law's article:

> "And this is why I would recommend actor-network theory. I would recommend it because it is weak. Because it is in dissolution. Because it has betrayed itself. Because it has turned itself from signal into noise. Because it no longer exists. Because it has dissolved itself into other ways of seeing, of writing, and of doing" (Law 1999:10).

ANT provide alternative ways of describing the world. In addition, as for IMP with regard to the Economy*, ANT has an outspoken propensity for the empirical. Most importantly, ANT is concerned with how anything becomes stable in a world of change. "Universality or order are not the rules but the exceptions that have to be accounted for," as stated by Latour (1997). It can therefore aid in accounting for the production of scientific facts.

Since my thesis is concerned with how the Environment* is formed, the scientific work necessary in order to connect the bumper beam to environmental impacts is of particular importance. The ANT toolbox consists of a number of concepts developed to trace the processes of such stable actor-network formations. The concepts are, deliberately according to Latour, meaningless in themselves to ensure that they should not be confused with the empirical world. Three of the more important concepts are actor-networks, translation and black box. Before digging into the specifics of the theory, it can be wise to state what ANT is *not*:

> "'Actor' in the Anglo-Saxon tradition is always a human intentional individual actor and is most often contrasted with mere 'behaviour'. If one adds this definition of actor to the social definition of a network then the bottom of misunderstandings is reached: an individual human – usually male – who wishes to grab power makes a network of allies and extend his power – doing some 'networking' or 'liasing' as Americans say… This is alas the way ANT is most often represented which is about as accurate as saying that the night sky is black because the astrophysicists 'have shown there is a big black hole in it'" (Latour 1997).

Instead, ANT can be viewed as a general method to investigate the formation of any stable entity, be it an organisation, a concept or a technology. Latour (1999a) stated that:

> "Far from being a theory of the social or even worse an explanation of what makes society exert pressure on actors, [ANT] always was, and

> this from its very inception (Callon & Latour 1981), a very crude method to learn from the actors without imposing on them an *a priori* definition of their world- building capacities" (p. 20).

Latour's project has to a large extent been focusing on showing and suggesting how to solve the artificial separation between the natural and the social. It is a critique of sociology for using what should be explained, the social that is, as the explanation. Nothing should be taken as an underlying structure and size should not be treated as a cause but an effect.

Actors, Networks, and Actor-Networks

Callon (1987) explained the relation between the actor and the network as follows:

> "The actor-network is reducible neither to an actor alone nor to a network. Like a network it is composed of a series of heterogeneous elements, animate and inanimate, that have been linked to one another for certain period of time. An actor-network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of" (p.93).

Even if the actor-network is non-reducible, there are certain traits of both actors and networks that have led to the consciously chosen term 'actor-networks'.

Let us start with the actor:

> "An 'actor' in ANT is a semiotic definition – an actant – that is, something that acts or to which activity is granted by others … [Actors] are not conceived as fixed entities but as flows, as circulating objects, undergoing trials, and their stability, continuity, isotopies has to be obtained by other actions and other trails" (Latour 1997).

This definition of actors is vague and sharp at the same time. The vagueness probably stems from the normal concept of viewing actors as human beings. Instead ANT focuses on the ability for everything, be it a knife, a human being, a bacteria, a pencil or anything else, to act or to make others act. The sharpness is connected to the requirement that the actor must in fact make a difference – it has to act – to be an actor. It is not just a placeholder taking up space in a description.

The inclusion of non-humans as actors has been problematic to several social scientists (e.g. Collins & Yearley 1992), but to erase the distinction between the social and nature, no entity should be given a favoured ontological position. Moreover, it is not only to ensure that no one is given a favoured ontological position that non-humans are included:

> "…[The] analytical question is this. Is an agent an agent primarily because he or she inhabits a body that carries knowledges, skills, values, and all the rest? Or is an agent an agent because he or she inhabits a set of elements (including, of course, a body) that stretches out into the network of materials, somatic and otherwise, that surround each body…The argument is that thinking, acting, writing, loving, earning – all the attributes we normally ascribe to human beings, are generated in networks that pass through and ramify both within and beyond the body. Hence the term, actor-network – an actor is also, always, a network" (Law 1992: 381)

ANT seriously considers the idea that the boundaries of a human being are blurry and Latour (1997) states this to be a 'law':

> "As a rule, what is doing the moving and what is being moved have no specific homogeneous morphism. They can be anthropo-morphic, but also zoo-morphic, phusi-morphic, logo-morphic, techno-morphic, ideo-morphic, that is '(x)-morphic'. It might happen that a generative path has limited actants to a homogeneous repertoire of humans or of mechanisms, or of sign, or of ideas, or of collective social entities, but these are exceptions which should be accounted for" (p. 380).

The network metaphor is also consciously chosen, but also readily open for misunderstandings as 'networks' are spreading like a disease in both scientific and non-scientific texts. Latour (1997) stresses that the networks in ANT have nothing to do with technical networks such as computer networks (which are totally organised) or social networks (which leave the world out of their analysis).

> "ANT aims at accounting for the very essence of societies and natures. It does not wish to add social networks to social theory but to rebuild social theory out of networks. It is as much an ontology or a metaphysics, as a sociology (Mol & Law 1994)"(Latour 1997).

This needs clarification:

> "More precisely it is a change of topology. Instead of thinking in terms of surfaces – two dimension – or spheres – three dimension – one is asked to think in terms of nodes that have as many dimensions as they have connections. As a first approximation, the ANT claims that modern societies cannot be described without recognizing them as having a fibrous, thread-like, wiry, string, ropy, capillary character that is never captured by the notions of levels, layers, territories, spheres,

> categories, structure, systems. It aims at explaining the effects accounted for by those traditional words without having to buy the ontology, topology and politics that goes with them. ANT has been developed by students of science and technology and their claim is that it is utterly impossible to understand what holds the society together without reinjecting in its fabric the facts manufactured by natural and social sciences and the artefacts designed by engineers. As a second approximation, ANT is thus the claim that the only way to achieve this reinjection of the things into our understanding of the social fabrics is through a network-like ontology and social theory.
> To remain at this very intuitive level, ANT is a simple material resistance argument. Strength does not come from concentration, purity and unity, but from dissemination, heterogeneity and the careful plaiting of weak ties" (Latour 1997: 370).

Networks thus have the advantage of not being confined into small categories with homogenous material, and it ends the speculation about all overlaps and void spaces:

> "Literally there is nothing but networks, there is nothing in between them, or, to use a metaphor from the history of physics, there is no aether in which the networks should be immersed…A network is all boundary without inside or outside. The only question one may ask is whether or not a connection is established between two elements. The surface 'in between' networks is either connected – but then the network is expanding – or non-existing." (Latour 1997: 370).

The real advantages come from escaping dominant views on space and size, in other words the perceived importance of the proximity of actors and the micro-macro-distinction. ANT contests that the closeness of actors is necessary for their connectedness and that an actor of larger size is necessarily more important than a smaller actor.

> "The first advantage of thinking in terms of networks is that we get rid of 'the tyranny of distance' or proximity; elements which are close when disconnected may be infinitely remote if their connections are analyzed; conversely, elements which would appear as infinitely distant may be close when their connections are brought back into the picture. I can be one metre away from someone in the next telephone booth, and be nevertheless more closely connected to my mother 6000 miles away; an Alaskan reindeer might be ten metres away from another one and they might be nevertheless cut off by a pipeline of 800 miles that make their mating for ever impossible…[The] notion of network helps us to lift the tyranny of geographers in defining space and offers us a notion which is neither social nor 'real' space, but associations" (p. 371).

The examples are obvious in print but it is easy to forget when one looks for relations between elements. Perhaps more important than how relations in ANT alter the view on distance is how they alter the view on size:

> "A network notion implies a deeply different social theory: it has no a priori order relation; it is not tied to the axiological myth of a top and of a bottom of society; it makes absolutely no assumption whether a specific locus is macro- or micro- and does not modify the tools to study the element 'a' or the element 'b'; thus, it has no difficulty in following the transformation of a poorly connected element into a highly connected one and back. A network notion is ideally suited to follow the change of scales since it does not require the analyst to partition her world with any priori scale. The scale, that is, the type, number and topography of connections is left to the actors themselves…[instead] of opposing the individual level to the mass, or the agency to the structure, we simply follow how a given element becomes strategic through the number of connections it commands and how does it lose its importance when losing its connections." (Latour 1997: 371)

It follows that:

> "A network is never bigger than another one, it is simply longer or more intensely connected."(Latour 1997: 371)

This alteration is necessary in order to avoid granting some actors extra power because they look big at the outset. The point is to grant the empirical world the right to make the explanations instead of relying on predefined views of what is important and what is not.

Latour is, however, quick to emphasise that the alteration of views is not the same as defining away distance and size and other "standard" variables in science:

> "This is not to say that there is nothing like 'macro' society, or 'outside' nature as the ANT is often accused to, but that in order to obtain the effects of distance, proximity, hierarchies, connectedness, outsiderness and surfaces, an enormous supplementary work has to be done (Latour 1996a)." (Latour 1997: 372)

Thus, the change of views is rather connected to a different understanding of the objects under study as well as a different way of making sense of them. Entities are no longer *either* physical and real *or* socially constructed:

> "The new hybrid status give to all entities both the action, variety and circulating existence recognised in the study of textual characters and also the reality, solidity, externality what was recognized in things 'out

> of' our representations. What is lost is the absolute distinction between representation and things – but such is exactly what ANT wishes to redistribute through what I have called a counter-Copernican revolution." (Latour 1997: 375)

Words and objects get mixed up as they do in everyday life and this dual nature is used constructively rather than being defined away at the outset. The result has consequences for understanding not only actors, but also networks and actor-networks.

> "…[ANT] is not about traced networks but about a network-tracing activity…There is not a net and an actor laying down the net, but there is an actor whose definition of the world outlines, traces, delineate, limn, describe, shadow forth, inscroll, file, list, record, mark or tag a trajectory that is called a network. No net exists independently of the very act of tracing it, and no tracing is done by an actor exterior to the net. A network is not a thing but the recorded movement of a thing. The questions ANT addresses have now changed. It is not longer whether a net is a representation or a thing, a part of society or a part of discourse or a part of nature, but what moves and how this movement is recorded." (Latour 1997: 378)

Much of the material here may seem overly specific and almost pretentious, but there is a reason for it:

> "ANT is not merely empiricist though, since in order to define such an irreducible space in which to deploy entities, sturdy theoretical commitments have to be made and a strong polemical stance has to be taken so as to forbid the analyst to dictate actors what they should do. Such a distribution of strong theory for the recording frame and no middle range theory for the description is another source of many misunderstandings since ANT is accused either of being dogmatic or of only providing mere descriptions. For the same reason it is accused of claiming that actors are 'really' infinitely pliable and free or, inversely, of not telling what a human actor really is after…[It] does not say anything about the shape of entities and actions, but only what the recording device should be that would allow entities to be described in all their details. ANT places the burden of theory on the recording not on the specific shape that is recorded" (Latour 1997), p.375.

Thus, to tell a real empirical tale, the instruments for doing so must be well specified. That is why time is spent here on sorting out what the concepts, the mechanisms or the processes are that can be used to understand the formation of stable entities, that is, actor-networks. This is particularly important as scientific facts are both good examples of stable entities and provide the foundation for the Environment*.

Translation

Translation is the building block of actor networks. It is the manifestation of interaction between actors and may happen in many ways. Latour (1986) describes it thus:

> "…the spread in time and space of anything - claims, orders, artifacts, goods - is in the hands of people; each of these people may act in many different ways, letting the token drop, or modifying it, or deflecting it, or betraying it, or adding to it, or appropriating it." (p. 267)

In order to align the interests of different actors, translation is needed and "is more effective if it anticipates the responses and reactions of the materials to be translated" (Law, 1992: 388). Translation is thus the act and outcome of carrying an idea or a material object forward:

> "Analysis of ordering struggle is central to actor-network theory. The object is to explore and describe local processes of patterning, social orchestration, ordering, and resistance. In short, it is to explore the process that is often called *translation* which generates ordering effects such as devices, agents, institutions, or organizations. So "translation" is a verb which implies transformation and the possibility of equivalence, the possibility that one thing (for example, an actor) may stand for another (for instance a network).
>
> This, then, is the core of the actor-network approach: a concern with how actors and organizations mobilize, juxtapose, and hold together the bits and pieces out of which they are composed: how they are sometimes able to prevent those bits and pieces from following their own inclinations and making off; and how they manage, as a result, to conceal for a time the process of translation itself and so turn a network from a heterogeneous set of bits and pieces each with its own inclinations, into something that passes as a punctualized actor"[7] (Law 1992:386).

The citation above may be difficult to understand. The consequences are 'easy', however, if we look at what ANT has achieved through their studies:

> "The empirical conclusion is that translation is contingent, local, and variable" (Law 1992:387).

Those things that are contingent, local and variable can certainly be interesting, but scientific facts show the exact opposite characteristics. Thus, there must be ways to make translations last, to make them into black boxes.

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[7] A punctualized actor is similar to an actor-network that is black-boxed.

Black box

A black box is what occurs whenever an actor-network is sealed in such a fashion that it can act as a single actor. Latour (1987) states:

> "I have used this term both too much and too loosely to mean either a well-established fact of an unproblematic object…The only way for new undisputed facts to be fed back, the only way for a whole stable field of science to be mobilised in other fields, is for it to be turned into an automation, a machine, one more piece of equipment in a lab, another black box" (p. 121).

Most of science is based on black boxes, on previously established truths that must be taken for granted. When carbon dioxide, measuring instruments, laboratories, scientific journals, and solar rays all are made into one single theory of climate change, we have a black box. This can serve as input for other sciences and also for political processes such as the Kyoto protocol negotiations.

Black boxes presuppose translations to be far from contingent, local and variable. Instead they must be durable and mobile. Both these features have to be inserted into the actors involved, the fabric of the actors cannot be easily dissolved and they must be able to travel. Such are the characteristics of many actors and actor-networks as shown in a number of ANT studies.

ANT, science and the environment

The first studies in ANT concerned the production of scientific facts (See for instance Latour 1983; 1987; Latour & Woolgar 1979).

> "They argued that knowledge is a *social product* rather than something generated through the operation of a privileged scientific method. And, in particular, they argued that "knowledge" (but they generalize from knowledge to agents, social institutions, machines, and organization) may be seen as a product or an effect of a *network of heterogeneous materials*.
>
> I put "knowledge" in inverted commas because it always takes material forms. It comes as talk, or conference presentations. Or it appears in papers, preprints, or patents. Or again, it appears in the form of skills embodied in scientists and technicians (Latour & Woolgar 1979). "Knowledge," then is embodied in a variety of material forms. But where does it come from? The actor-network answer is that it is the end product of a lot of hard work in which heterogeneous bits and pieces – test tubes, reagents, organisms, skilled hands, scanning electron microscopes, radiation monitors, other scientists, articles, computer terminals, and all the rest – that would like to make off on their own are juxtaposed into a patterned network which overcomes their resistance.

> In short, it is a material matter but also a matter of organizing and ordering those materials. So this is actor-network diagnosis of science: that it is a process of "heterogeneous engineering" in which bits and pieces from the social, the technical, the conceptual, and the textual are fitted together, and so converted (or "translated") into a set of equally heterogeneous scientific products" (Law 1992:381, emphasis in original).

The output of science, the texts, travel easily through actors like books and journals - and the texts are made credible, their actor-network status stabilised, through alluding to still more resistant materials and the trails they make materials undergo in the hands of scientists. Even the texts themselves creates references to durability:[8]

> "As I have shown elsewhere, it is possible to define scientific literature stylistically by following how the authors, instead of alluding to documents, mobilize them in the text as so many *inscriptions* (tables, graphs, pictures, diagrams). It is even possible to decide if a narration pertains to a harder or a softer field of science by looking at the type of inscriptions and the way they are piled on top of one another so as to create, for the reader, the impression of a harder or softer reality" (Latour 1988:8).

ANT will be guiding the description of the environmental aspects of the bumper beam. All the concepts treated here will be central to explain the formation and texture of the Environment*. In addition, in the book *Science in Action*, Latour lays down rules and principles to follow when studying sciences. I have picked out four rules and two principles that are deemed especially important for studying the Environment*. These rules and principles are supposed to steer the way the empirical data is collected and the empirical description is written to avoid a presentation where the conclusions are given in advance.

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[8] Latour (1988) also describes the tedious efforts by Einstein in securing non-deceitful translations to sort out the actor-network known as the relativity theory: "Obviously, Einstein is both a latecomer in this long history [of centres of calculation] and a significant contributor to it. His obsession with transporting *in*formation through *trans*formations without *de*formations; his passion for the precise superimposition of readings; his panic at the idea that observers sent away might betray, might retain privileges, and send reports that could not be used to expand our knowledge; his desire to discipline the delegated observers and to turn them into dependent pieces of apparatus that do nothing but watch the coincidence of hands and notches; even his readiness to jettison what common sense cherishes provided the equivalence of metrological chains be saved" (Latour 1988).

The rules are given in citations, while my reasons for employing the specific rule are argued for in between.

> "1. We study science *in action* and not ready made science or technology; to do so, we either arrive before the facts or machines are black boxed or we follow the controversies that reopen them" (Latour 1987:258).

It is not enough to describe environmental issues as they are presented in science or in mass media in order to show what the environment really is. To do so, the different elements making up an environmental problem must be scrutinised and their history tracked in order to avoid taking the elements for granted.

> "2. To determine the objectivity or subjectivity of a claim, the efficiency or perfection of a mechanism, we do not look for their *intrinsic* qualities but all the transformations they undergo *later* in the hands of others" (Latour 1987:258).

In other words: an idea, a theory or a machine is not right by definition alone. They need usage to become right and are transformed in the process. The quality of an element therefore cannot be described by looking at the element itself. This rule is important to avoid a description where elements are taken for granted because their extended presence makes them look to be of better quality.

> "3. Since the settlement of a controversy is the *cause* of Nature's representation, not its consequence, we can never use this consequence, Nature, to explain how and why a controversy is settled" (Latour 1987:258).

When the environment is described, the results from science cannot be taken as the starting point. Facts from natural sciences are not present out there in nature for researchers to reveal, so appeals to nature should be avoided when presenting the elements that make up the environment.

> "4. Since the settlement of a controversy is the *cause* of Society's stability, we cannot use Society to explain how and why a controversy has been settled. We should consider symmetrically the efforts to enrol human and non-human resources." (Latour 1987:258).

Society is just as unsuitable as Nature to be the root cause of everything, as Society is also created. Thus, this fourth rule is necessary to complement the third and to stick to a description where elements are not predetermined to belong to either category.

The principles:

> "1. The fate of facts and machines is in later users' hands; their qualities are thus a consequence, not a cause, of a collective action.

This principle is similar to the second rule and tells me to avoid the use of the elements themselves as an argument for how they are used. Rather the elements usage should be tracked and described in order to understand why they disappear or are enforced.

> 2. Scientists and engineers speak in the name of new allies that they have shaped and enrolled; representatives among other representatives, they add these unexpected resources to tip the balance of force in their favour." (Latour 1987:259)

This last principle is guiding the understanding of how environmental problems grant weight and become important. The elements in the environment are not enough in themselves, neither are the researchers describing them, but in combination they can make environmental issues important and lasting.

2.2.3 Why two theories?

Why the two are used must be motivated by their potential to add to the issues at stake. Do the theories produce credible descriptions of the Economy* and the Environment* and is it then possible to compare the descriptions? Conflicting theories with mutually exclusive assumptions cannot be used. They must be similar enough to produce comparable descriptions, yet different enough to produce complementary descriptions. Thus, the important question becomes: What are the differences between them and what are the similarities?

Their weaknesses and strengths are different: where IMP seeks to confine itself to a world of business-to-business marketing (although alluding to consequences for the view on markets and thus the economy), ANT focuses on a more general theory of how to produce knowledge (or any other stable entity).

The most striking difference between the two approaches is the boundaries they have imposed on themselves with regard to which objects to study. IMP has constrained itself to only deal with empirical phenomena within the industrial sphere, while ANT seems borderless and applicable for studying whatever phenomena where anything gets stabilised. This difference also points to some of the strengths and weaknesses of the approaches. One of the advantages of IMP is that it encompasses a body of research where a lot of knowledge about the working of industry is gathered, though this has the danger that the model is confused with the empirical. It also facilitates the idea that all the actors, activities and resources are there to affect an economic output. ANT does not encompass anything more than a metaphysical language, a framework for capturing whatever aspect of the social (which in the ANT meaning also encompasses nature). There is less danger of believing in the framework, but it is also harder to spot why any of the actors act at all.

Another difference is the view on stability and change. From the very beginning, one of the propositions of IMP has been that stability is one of the premises for change. In ANT, stability is the exception; the phenomena that must be explained. This difference may be superficial and only relate to the phenomena that these approaches have sought to explain. It may, however, be a real and important difficulty and this issue will be taken up for discussion in the last chapter.

Regarding the similarities, i.e. the conditions necessary for bringing information from both together, I believe the presentations have shown that there are more similarities than just the common term 'network' and a reluctance to be seen as 'classical' theories. According to Mattson (2003), when comparing ANT to four marketing theories:

> "ANT's by far 'closest neighbour' is the markets-as-networks view. Markets-as-networks also is specific about the need to consider both social and technical interdependencies but is not at all explicit in how human and non-human actors are methodologically related and not clear about the performative aspects. As to the methodology for studying dynamics ANT is more 'precise' than markets-as-networks. Markets-as-networks studies focusing on technological innovation (e.g. Håkansson 1989; Lundgren 1995) demonstrate an explicit link between science and practice." (p. 16).

McLoughlin and Horan (2002) state that two other IMP researchers rely on ANT to describe the network metaphor:

> "In support of their position against a more explicit definition [of networks] they enlist Latour (1993, pp. 3-4) who has described the network metaphor as '…more supple than the notion of system, more historical than the notion of structure, more empirical than the notion of complexity, the idea of network is the Ariadne's thread of these interwoven stories…which remain more invisible than spiderwebs.'" (p. 538)

There are also other instances of IMP researcher taking up ideas from ANT and applying them to industrial networks, for instance Håkansson and Waluszewski (2002) using the term translation and Araujo (2007), Kjellberg (2001) and Helgesson (1999) employing ideas from ANT to understand marketing and market-making.

Using IMP concepts to understand the Environment* could possibly produce an interesting picture, although earlier studies where the environment plays a role let the environment be a backdrop against which other effects are studied (see e.g. Harrison 1999; Harrison & Easton 2002; Håkansson & Waluszewski 2002). Using IMP to describe (and thus explain) the Economy* is much more natural, as most IMP studies are focusing more or less explicitly on economic questions.

It is harder to rule out the use of ANT to produce descriptions (and thus explanations) of the Economy*. According to Law, ANT is a general method to capture the empirical:

> "[science] isn't very special. Thus what is true for science is also said to be true for other institutions. Accordingly, the family, the organization, computing systems, the economy and technologies – all of social life – may be similarly pictured. All of these are ordered networks of heterogeneous materials whose resistance has been overcome. This, then, is the crucial analytical move made by actor-network writers: the suggestion that the social is *nothing other than patterned networks of heterogeneous materials*." (Law 1992:380 italics in orginial)

However, this is not the only reason. There is also an explicit interest shown by ANT researchers into economic issues where ANT's basic worldview is employed in order to understand economy (see for instance Callon 1998a; 1998b).The reason for choosing IMP is thus that it, at the outset, seems better equipped to describe the economy network.

It follows from both the presentation of the theories and the discussion here that the main argument for applying both approaches is that they each carry a history of earlier uses. The applications have coloured the way the approaches are presented by different theorists and also my interpretation of them (both the approaches and their presentations, if these can be separated at all).

The most important similarity, the one concerning the underlying assumptions about the working of the world, will be treated next. A more thorough discussion of the usefulness of the approaches in the thesis will be provided towards the end of the thesis.

2.3 The world and how to gain knowledge about it

Theses within many established sciences, or established paradigms to use the words of Kuhn (1962), need not worry too much about the relation to reality or the methods to uncover its secrets. This thesis, concerned with the relation between nature (as entities we value and want to care for) and society (as economics and possibilities for monetary gain and sustained production) and employing two different "theories", must have a conscious relation to and presentation of such issues. This presentation could have been carried out using terms such as ontology (what the world is), epistemology (how we can gain knowledge about the world) and axiology (what the researcher's values are). However, imposing such terms already establishes a view of the world as something disconnected from the human mind and the research process as distinct from the values of the researcher. I believe such predefined restrictions on what the world is and how it can be captured hamper the possibility of understanding the empirical world. Other standpoints may prove more valuable, for instance allowing for the empirical to be "righteous" (i.e. not in need of a theory to be understood) and viewing the world as process and relationality.

2.3.1 The world as process and relationality

Since I will bring IMP and ANT together in the analysis, one of the requirements should be that they have compatible views on reality and ways to know more about it. At the outset, it is hard to tell whether this is the case. Researchers within IMP have not spent much space in articles and books on clarifying the philosophical position.[9] One clear exception is Easton (1992; 1995) who has clearly stated his position as a critical realist and also the usefulness of this perspective when investigating industrial networks. Actor-network theorists have been much (too?) occupied with the philosophical underpinnings of their approach. In fact, the philosophical underpinnings and the approach are almost inseparable, as the project is a new way of describing the world, freed from the dichotomies proposed by modernity (Latour 1993). In practice, this means that nature and society should not be divided, they are indivisible parts of one another and every explanation of a phenomenon should include both humans and non-humans, that is we should not believe that society - or nature - in itself can explain anything. The operational consequence of this is that the world is the actor-networks it encompasses and that the empirical gives the best explanation of the world. A similar argument can be found in Håkansson and Waluszewski (2002):

[9] There are of course several examples of such clarifications in PhD theses produced within IMP (e.g. Baraldi, Gressetvold and Holmén), but there are few articles or books that cover such issues written by established researchers.

> "Regardless of one's standpoint in this discussion [generate vs. verifying theory], the main attention is still directed to the issue of if and how a qualitative approach can contribute to theory. Seldom is the opposite issue dealt with: *if and how a qualitative approach can be used to develop the view of the empirical world*. However, even if this is a total clash with what is brought forward in a positivistic context, this is exactly what both researchers and companies struggle with every day" (p. 16, emphasis in original).

Being interested in the empirical world means the researcher must pay attention to what the empirical has to say about the subject rather than depend on predefined categories. I have been involved in a constant process of simultaneously coming to grips with the empirical world and the theories employed to make sense of it. However, this does not mean reverting to theories that are already fixed with what the empirical is:

> "Categories and things may make it easier for us to grasp reality but they also hide its underlying complexities…[they] suggest that thinking is directed by a centrally focused perspective which fixes its forms and thus loses any sense of the human world as a field of dynamic and mutable relations" (Cooper 2005:1690, emphasis in original).

I want to get a grip on the 'dynamic and mutable relations' and using IMP does not counteract such an approach. In fact, it may support the view that relationships are as substantial as things:

> "All business interaction is part of a process that involves resources from far wider in the surrounding network of actors than from the small number of actors that are apparently involved in it. Even more importantly, the tangible characteristics of business such as companies and their products, sales and purchases are no more substantial in an interactive world than the apparently ephemeral relationships that exist between those companies" (Ford & Håkansson 2006a).

There is a relationship between the existence of relationship and the space that the relationships exist in:

> "Space, any space, is much more than the container of things; it 'is not the setting (real or logical) in which things are arranged, but the means whereby the positing of things become possible' (Merleau-Ponty 1962:243). Things derive their character and thinghood from the space through which they re-late to each other: 'This means that instead of imagining (space) as a sort of ether in which all things float…we must think of it as the universal power enabling them to be connected' (Merleau-Ponty 1962:243). Connection and relationship are the vehicles that human agency carves out of pre-objective space so that its latency

> can be re-lated through the meaningful arrangements of the things and objects that make up the human world." (Cooper 2005:1694)

The relationships and the effects they produce assume structural properties that again deem the relationships to be a process:

> "…Actor-network theory assumes that social structure is not a noun but a verb. Structure is not free-standing, like scaffolding on a building-site, but a site of struggle, a relational effect that recursively generates and reproduces itself. The insistence on process has a number of implications. It means, for instance, that no version of the social order, no organization, and no agent, is ever complete, autonomous, and final" (Law 1992: 385-386)

Latour's book "Pandora's Hope" (1999b) starts with the author being asked if he believes in reality. He is astonished by the question and the rest of the book is an attempt to describe how he views reality as a construction, but not as a social construction only existing within a social sphere. The world is thus a construction but not a social construction as proposed by Berger and Luckmann (1966). It is a "real" construction made of heterogeneous material. Every entity in the construction can only be understood by its relation to other entities, i.e. no entity can ever be described without describing its relation to one or more other entities. This is what I will refer to as a relational view of the world. There is no sharp, if any, distinction between relationality and relativity. I am using the former term to pinpoint the relational nature of relativity so beautifully expressed by Deleuze (1993):

> "Relativism is not the relativity of truth but the truth of relation."

According to Cooper (2005), the empirical material I am studying, the bumper beam and its place in the car (industry) is in itself coupled to an illustration of relationality:

> "The history of modern methods of production illustrates relationality as an all-pervasive force in the development of the modern world. Industrial production is increasingly focused on the production of *parts* rather than whole, finished objects: the mass production method used in the manufacture of the motor car conveniently illustrate production as re-lating of *parts*." (p. 1706, emphasis in original)

The relationality, Cooper (2005) writes, must be understood:

> "as an active condition of betweenness in which individual terms can never exist or find themselves since they are always mediated by the neutrality of the latent. Never a thing in itself, relationality tells us that we are also parts in the 'movement of being' and what constitutes us is the interactive re-lating that occurs *between* parts: the scientist exists in

> the interior of the research activity and not outside it as an external and independent observer; the motor vehicle drives me just as much as I drive it. Relationality says that we are extension of our supports and props just as much as they are extensions of us; it reminds us of the essential reciprocity between ourselves and the world of objects." (p. 1704)

This specification of relationality tastes of déjà vu, similar statements about the nature of relationships have been made in the presentations of both IMP and ANT.

Another reason for claiming that the approaches have a similar worldview is that researchers associated with them are producing similar texts (mainly monographies) resembling what are often referred to as case studies. This study will be no exception and the next chapter will present the case study object(s).

2.4 Method or how the empirical is captured

ANT and the Industrial Network Approach seem to agree on the empirical focus. Latour tells me to "Follow the actors!" while Håkansson says: "Let the case speak!" As such, they are both empirical and analytical strategies. However, what observations to capture and the way of capturing them and writing them down are not evidently the same in the two approaches. Therefore I must be cautious about where they are conflicting and where one has a concern not shared by the other.[10] Ultimately, I should have been two different researchers doing two different studies, but besides being impossible, it would also not have allowed me to capture the conflict I am interested in. In addition, there will always be questions about who the actors are and what the case is. I do, however, try to sort out two different cases, or two different descriptions of the same case, as will be explained in the next subchapters.

The easy way out would be to state that the thesis is based on a case study design according to the principles laid out by Yin (1989). Many articles and theses use this reference to justify the choice of a case study without specifying further the advantages or disadvantages or even the way the study has been conducted. There is, however, a reason for choosing a case study design. One of them being that case research has been a key method (among others) for researchers operating within the industrial network approach (Dubois & Araujo 2004). Moreover, a case study does not seem to be

[10] A more lengthy discussion on the advantages and disadvantages of applying both approaches is provided towards the end of the thesis

disagreeable from an ANT point of view, although the word itself is rarely used. What is presented here is a short discussion of the advantages and disadvantages with case study research, followed by a description of how the case study is undertaken.

2.4.1 Case study design

Case studies are widely recognised as being useful for producing scientific knowledge (see e.g. Andersen 2003; Dubois & Araujo 2004; Eisenhardt 1989; Yin 1981; 1989).[11] Even some positivists are in favour of the hypothesis-building capacities of case studies. One does, however, easily get the impression that case studies are ranked second to "proper" scientific methods, that they can only be used as pre-studies before the real investigation begins. The real investigation is then considered to be model testing. I have the opposite belief: statistical surveys and testable methods can be useful for generating problems that can be investigated more closely with the aid of a case study. In other words, case studies are able to produce more substantive knowledge than any survey. This is probably connected to the belief in process being more important than structure and the empirical being better to speak for itself than through the meta-language of any researcher. Validity issues will then be treated differently than in a statistical survey, but this issue is discussed in the next section, as this is the place for describing how the case study is organised.

I was initially concerned with how I could find empirical instances of the Environment* and the Economy*, and especially where the two meet. As both the Environment* and the Economy* as the terms used in this thesis are vague networks at the outset, part of the research process consists of determining the boundaries of these analytical constructs. From the start, bumper beams produced and developed in the relationship between Volvo and Hydro was supposed to be the tool to focus the case description. These bumper beams belong per definition to the economy network, so most of the activities of which they are the objects must be of an economic nature. Thus, processes that clearly seem to be contrary to the "normal" stream of processes are probable instances where Environment* makes its way into the Economy*. I still believe this description of bumper beams to be viable to produce insights about the Economy*, but several questions popped to the surface: What if investments are carried out to improve Economy* but fail? What if investments are carried out to improve Environment* but improve

[11] This is not to say that they are undisputed, as they are also recognised as being misused, ill-devised and poorly conducted in many instances.

Economy* at the same time? What if investments are carried out to improve Economy* but improve Environment* at the same time?

The revised approach has been to include two descriptions of bumper beams. The first one is based on the line of thought whereby they are described through the relationship between Hydro and Volvo. The focus is on the activities, resources and actors involved in their production and how these have changed or remained stable over time to capture the evolvement and content of the Economy*. The second is a description of bumper beams as a research report. Instead of seeing them as the physical outcome of an industrial process, they are viewed as the outcome of scientific research where I put special emphasis on the bumper beams' environmental characteristics and thus research that is connected to environmental issues. The environmental issues are traced through texts to capture the evolvement and content of the Environment*. Figure 2-3 shows a model of the two descriptions and the relationship to bumpers.

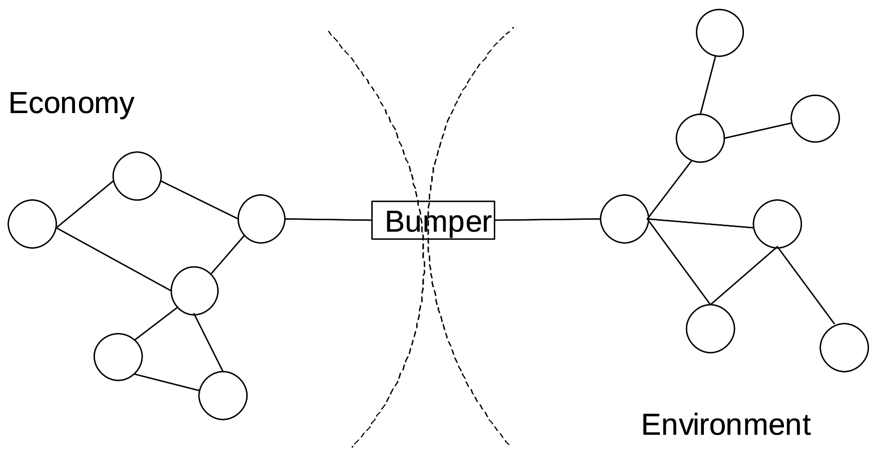

Figure 2-3 A model of the descriptions of the Economy and the Environment* and the relationship to bumpers.*

The left side of Figure 2-3 shows the industrial network involved in producing bumpers (and simultaneously the Economy*). On the right is the scientific network involved in producing the environmental characteristics of the bumpers (and thus the Environment*). The bumper is one element where a connection between the Economy* and the Environment* exists, but there may be connections also between other elements as this thesis will try to scrutinise.

Industrial production of bumper beams is not disconnected from scientific production of bumper beams. Both Hydro and Volvo make internal use of research in relation to the bumper, both in making it material and in using it in different texts such as annual reports and marketing material. Volvo and Hydro are also directly involved in research, so that the physical bumper beams also serves as input to research texts. The article used as a starting point for describing the Environment* even looks at the environmental properties of bumper beams produced at Raufoss. Ideally, I want to produce two 'pure' descriptions, meaning that they do not show any connections between research and the Volvo-Hydro relationship. However, in practice this will be cumbersome and may add problems when information from the two descriptions is brought together towards the end of the thesis. Whether I have used two descriptions of a single case study or two different case studies is not something I will discuss here, as it is deemed unimportant. I have constantly reflected on issues such as the unit and level of analysis and the choices will come through in the text, making a lengthy formal discussion unnecessary.
To construct the descriptions, different sources are used to produce information, to complement each other or to verify or clarify what one source has stated. The most important sources for empirical data in the thesis are interviews, documents, observations and physical artefacts.

Interviews

Much of the material for the thesis has been gathered through interviews and the information from these is especially important for the first description, the one about the Economy*. Not meaning that everything every interviewee said has been of importance, but the human beings who are part of the production and development of bumper beams within the relationship between Hydro and Volvo have guided the first description. Their emphasis on various issues has sent me in many directions and they have been one of the important sources for documents. Interviews have not been as important for the second description, although information from interviews has helped in finding the research streams associated with bumper beams.

I have tried to keep the interviews open-ended in the sense that I have not had a complete list of questions, but rather an interview guide with a few central themes to be elaborated. These themes have varied according to the positions of the interviewees and according to my knowledge of the case and what information I have believed to be useful.

A few interviews have included more than one interviewee and I have found these to be extremely useful. They have turned into a dialogue between the industrial representatives where I have only raised the issues to be discussed.

However, the use of this format has only been used a few times and it is not only associated with positive issues. In addition to being a hard interview strategy to pursue due to the time constraints of possible interview subjects, it also creates a risk that the interviewees will be afraid to give 'silly' answers.

I do try to maintain an air of 'stupidity' in every interview, in the sense that I will not pretend to understand issues I am not sure I have understood, although I must admit that I have a propensity to appear rather more intelligent, which creates some resistance in asking the really 'silly' questions. Hence, I also believe it to be important to reflect on the interviewees' motivation for giving the answers they do. Many of them have expressed their concerns on the balancing act between economic issues and other issues (such as environmental issues or family life) in their private and working lives. These concerns, as well as how they affect their answers, should be taken seriously. Although a general strategy on how to handle such issues is hard to define, it probably boils down to treating the interviewees with trust and respect while at the same time using several sources for documentation.

Most of the interviews have been performed face to face, which allows for other types of interaction than just verbal. Whenever an issue has been unclear and where a figure could provide a clarification, I have asked for such. The interviewees have also spontaneously used drawings and/or other support material (such as a physical bumper beam) to make me understand the issues. A smaller number of interviews have been undertaken on the phone due to long distances or tight time schedules. E-mail has been used as a tool to establish initial contact with interviewees and for answers to 'simple' questions with already established contacts.

Some of the early interviews were conducted using a tape recorder. However, I discovered that the tape recorder was affecting the amount of information the interviewees were willing to share, as my notes (which were made in addition to the recording) revealed that more interesting information occurred whenever the tape recorder was shut off. Its seemingly disturbing presence made me abandon the use of it. Instead I have relied on writing fast, using quotation marks wherever I have felt an important statement to be made, one where there was a need to be true to the original formulation.

To further ensure the information to be correct, the interviewees have been given the transcripts and thus the possibility to correct misunderstandings, to tell me what they would not like me to cite and to add information they felt was missing.

A list of the interviews conducted is presented in Appendix A.

Documents

Documents include a range of textual accounts from personal notes via presentations, formal contracts and marketing leaflets to scientific articles, to mention but a few. The use of documents is different for the two descriptions. For the industrial description, texts have been instrumental in providing understanding of the different processes involved in producing and developing bumper beams both in a contemporary and historical setting. Some of the material is of a presentational nature, such as annual reports, environmental reports and PR brochures. The way these are used resembles how Håkansson and Waluszewski (2002) use written material:

"As Atkinson and Coffey (1997: 61) emphasise, 'rather than ask whether an account is true, or whether it can be used as "valid" evidence about a research setting, it is more fruitful to ask ourselves questions about the form and function of texts themselves'. The written material has certainly been important. It helped to grasp the formal views of different actors on different issues and, in particular, to understand technical aspects related to the provision and use of LWC paper." (p. 21)

The importance of documents is greater for the second description, the bumper beam research case. To trace research on and connected to bumper beams involved finding scientific articles and following their citations. The majority of the articles lead to sites where aspects of the material world are translated into numbers, figures, graphs and text. To get inside automotive research, I have become a member of the Society of Automotive Engineers to access databases of conference information and journals connected to research on cars. I performed an extensive literature search in journal and library databases and the specifications of the databases and searches are given in Appendix B.

Although the uses and sources for documents are different for the two descriptions, the documents themselves have cross-fertilised the descriptions. What I have learnt from industrial documents has aided in understanding the research documents and vice versa.

Physical artefacts

Both the case about a physical artefact in itself and the processes involved in making bumper beams (both industrially and scientifically) are packed with physical artefacts. The economic description of the production and development of bumper beams is strongly connected to the production technologies used. Casting ovens, extrusion presses, die tools and forming robots all play an important part in creating bumper beams, as well as the economics connected to them. Many of the same physical artefacts are important in creating the scientific/environmental bumper beams, albeit more indirectly than in the industrial case. Other artefacts are instrumental in producing knowledge about the production technologies, e.g. laboratory equipment to measure strength or emissions and computers to translate the physical artefacts into graphs, tables and texts. I too will have to translate all the artefacts I encounter into text and try to refrain from only using already established textual accounts of them. Nonetheless, existing texts are important to make sense of the artefacts role in producing the Economy* and the Environment*.

Observation

The use of direct observation has not been systematically undertaken in the study. I have not had free access to any of the study sites, but have on a few occasions, upon request, been allowed to watch the processes involved in making physical or scientific bumper beams. The latter is unfortunately mostly done in a site where research is connected to Hydro. Ideally, it should have been disconnected from the industrial production of the bumper beams. Nonetheless, what is more pressing is what I can get out of observations; how can they be used to describe bumper beams and understand the Environment* and the Economy* better? It is hard to pinpoint at what time actors are acting economically or environmentally. This is recognised by Håkansson and Waluszewski (2002) who write:

> "As business and economic researchers, we usually focus on the economic outcome of an industrial system as a whole, or on how the economic outcome is distributed between subunits such as companies. However, as we already have illustrated earlier, there is reason to question whether a focus on economic considerations really is the most fruitful way to grasp how an economic outcome is created. Thus, our empirical interpretation is that company life very often is far from being purely a matter of economic issues. Considering all the problems that companies wrestle with daily, it is probably more fair to claim that our research objects deal primarily with issues related to *technical and social elements*. Certainly the activities of any such unit have economic effects – but these are mainly consequences of expectations and actions that are manifested in technical and/or social dimensions. Here we have a first basic assumption: *an excessively narrow focus on economic dimensions alone will limit our understanding of how companies function and therefore also how their economic outcome is created*." (p. 17, Italics in original)

I believe one of the important insights from observations to be an increased understanding of the tasks the actors perform. It is crucial to be able to impart the atmospheres and the spaces (both physically and mentally) in which the actors operate. I have to simplify and extract to construct a written account of what happens, but I should not reduce the complexity the actors are facing more than they do themselves.

The different sources cannot clearly be separated as documents and interviews may be needed to make sense of observation and physical artefacts and vice versa. Just looking at a machine like an extrusion press (used in making aluminium profiles) and trying to explain how it affects production is impossible. The way it operates is hidden behind the exterior shell and it needs to be picked apart, not literally but through documents, interviews and observation in order to make sense of the production setting.

2.4.2 Organisation of empirical data

During the PhD process, I have learnt that research is about systematics without rigidity. The only way to ensure a trustworthy study is to keep a good record of all data that is gathered and how it is translated into information for the thesis. The record keeping must, however, allow for restructuring when the material (or the researcher) points to new combinations of the data.

When the thesis work started, I had too little of both experience and training in collecting and storing data for a social science study. I had one single notebook used for internal seminars, interviews, reflections and whatever else I needed to write down. Interviews were transcribed and stored in an Access database, while other documents were more randomly distributed in folders on the computer and piles on the desk. As the focus of the study became clearer, I gained experience in ordering and read useful tips. The piles were reshuffled and categorised in ring binders, the folders on the computer were systematised and two extra notebooks were acquired. One for writing comments on interviews and reflections on how the interviews and other material could be used in the thesis, while the other is used from the "opposite" side, as it contains metaphysical and conceptual reflections on how to develop the thesis with questions and suggestions (to myself) on what empirical material that is needed. The folders on the computer were organised according to a similar logic.

2.4.3 Making the empirical textual

The collection and organisation of empirical data are intertwined with the process of creating the research text, more specifically this thesis. I have constantly been concerned with the way to present the empirical material in

a text that actually renders the relations between the Environment* and the Economy* visible. When expressing my concerns to my supervisors, I have often been told to first write empirical material and then start worrying about the problems of structuring the text. There is, however, a mutual dependency between the structure and the substance that makes it into a highly iterative process. Being faithful to the empirical material requires keeping my eyes open for findings and directions I had not anticipated. This explorative nature of the study calls for an approach to the writing and structuring of the text that is both inductive and deductive in nature. Such an approach can be found in Peirce's (1934) argument of abduction. Instead of going from rule (all balls in the urn are red) to case (the sample is taken from the urn) to result (all balls in the sample are red) as in deduction, or from case (the sample is taken from the urn) to result (all balls in the sample are red) to rule (all balls in the urn are red) as in induction, abduction is something in between. In abduction, one goes from the rule (all balls in the urn are red) to result (all balls in the sample are red) to case (the sample is taken from the urn). Dubois and Gadde (2002) have built on Pierce's idea and proposed a strategy called "systematic combining" for case research. The strategy involves matching of an analytical framework, the empirical world, the case and theory.
Having a strategy for the writing is important, but still the cumbersome and painful effort of writing down all the words and sentences remains. Latour (2005) stresses the importance of writing; claiming that it is only through writing that we make social connections traceable. In his words:

> "A good ANT account is a narrative or a description or a proposition where all the actors *do something* and don't just sit there. Instead of simply transporting effects without transforming them, each of the points in the text may become a bifurcation, an event, or the origin of a new translation. As soon as actors are treated not as intermediaries but as mediators, they render the movement of the social visible to the reader. Thus, through many textual inventions, the social may become again a circulating entity that is no longer composed of the stale assemblage of what passed earlier as being part of society. A text, in our definition of social science, is thus a test on how many actors the writer is able to treat as mediators and how far he or she is able to achieve the social" (pp. 128-129).

I believe the abductive strategy to be useful also for the ANT description of the Environment*, as I believe Latour's advice on writing to be useful also for the IMP description of the Economy*. Hence, these are the tools aiding me in writing.

In practice, writing a case where all dimensions are changing cannot create anything but confusion. Some elements in the description need to be fixed in order to capture the dynamics of the other elements. In the description of the Economy*, this is ensured by creating three pictures of the structure of the network involved in the development and production of bumpers and bumper beams at three different points in time: 1970, 1985 and 2006. The differences between the pictures provide a starting point for revealing the elements in the activity layer, the resource layer and the actor layer crucial to produce Economy*. The specific years were chosen due to information available at an early stage of writing the thesis. 1970 was selected because bumper production had "settled" at Raufoss that year while major changes were just down the road. Thus, it provides a ground state for the bumpers and the adjacent network. 2006 was the year most of the description of the Economy* was written, hence it was a present state, making it relatively easy to check numbers and if actors, resources and activities really were present. Although 1985 is not situated as the exact midpoint between 1970 and 2006, it was picked both for availability of data and for being a year preceding major changes in the network. Elements are presented in an almost chronological order, even if some of the material has had to be sorted according to themes.

There may be too great a reliance on the "big" events. Ford and Håkansson (2006a) touch upon this problem:

> "One way for researchers to deal with "lumpy" interaction is to identify "significant events" or "critical incidents". This approach clearly provides historical information, but has similar boundary problems to those of "episodes". More importantly, the idea of critical incidents also involves assumptions about the causality of outcomes that are likely to be unwarranted in a situation of complex, multi-party interaction" (p. 11).

The case covers a period of almost 40 years and I have not found a way to escape the seemingly causal relationships between what is labelled 'important' from the outset, such as a new machine or an acquisition, and the resulting Economy*. A study of micro processes involved, with all the minor changes and adjustments involved in the major changes, could give a better actual picture of the creation of Economy*. It is, however, deemed unfeasible for this study both in terms of its aim and its scope. The main focus is to present those elements that have been instrumental in confining the Economy* during the time span presented.

Another point taken up by Ford and Håkansson (2006a) is related to where the story begins:

> "One important consequence of the importance of time in interaction is that it is difficult to suggest that there can be such a thing as a new network. If we observe a network for the first time, then what we are actually doing is isolating part of a pre-existing and wider network...Each actor brings its own baggage from the past. This phenomenon is familiar from technological studies where path-dependence has been identified as a key issue, but here that path dependence is within a wider context. Path dependence means that researchers need always to look behind current patterns of interaction to what has preceded them and framed their evolution" (p. 10).

As a consequence, information about the companies and their evolving relationship prior to the "true" beginning of the case is provided.

In the description of the Environment*, the fixed portion of the case lies in the theory guiding the empirical study and the choice of a starting point. As we learnt in the description of ANT, every actor presented in the study must have connections to other actors. By choosing a specific article to be the 'source' from which to capture the Environment*, no actor should be present in the description that is not connected to this article. The article itself is chosen for its explicit connecting of bumper beams at Raufoss to environmental issues. Following from the nesting process that starts from one specific article, the description of the Environment* is presented in an almost opposite chronological order.

The most important point for the description of the Environment* is to display the elements decisive for its constitution between 1970 and 2006. Hence, the elements of the Economy* and of the Environment* can be compared in the later chapters to see if connections exist. In order to make the comparison easier, both the chapters on the Economy* and on the Environment* end with a timeline showing the changes of elements. The timelines also make it possible to investigate whether an element has been transferred from the Economy* to the Environment* or vice versa. To ensure symmetry between the two descriptions, the summary of the description of the Environment* includes pictures of the structure of the scientific network from 1970, 1985 and 2006.

The organisation of the material and the choice of what empirical material to include and what to leave out is critical to how the thesis is understood. Still, the only test of whether the right choices are made is whether the reader deems the text valid.

I have strived to create a text that is accessible to people without detailed knowledge of either industrial production or scientific production of bumpers. The writing styles in the sections on the Economy* and the

Environment* are deliberately made different to reflect both the differences in the theories utilised to produce the chapters and the actual differences between the two production systems. One of the consequences has been that the chapter describing the Environment* contains some rather long citations. This is to show how the elements (i.e. the actors) in the Environment* are described in the words of the researchers.[12] At the same time, readability has been a crucial issue. Still, the text is a PhD thesis and must be academic, that is, in accordance with operating procedures within academia. This means that parts of the text may be inaccessible for readers without a relationship to scientific language.

2.5 Explanation, validity and transferability

Whereas the description is seen as the explanation in actor-network theory, the normal way of writing a thesis within the industrial network approach is to write a "pure" empirical case followed by an analysis. Still, the latter's inclusion of an analysis seems more like a pragmatic approach to make the writings "edible" for other scientists within economics. The view of science by the two approaches will have consequences for how explanations are made and how validity can be ensured, or if in fact such terms are useful to discuss the "scientific-ness" of the text.[13]

2.5.1 Scientific explanation

The question of what an explanation really *is* is one of the more troublesome within science and one of the reasons for scientific controversies. Latour (2005) makes an effort to calm down those of us who believes in thick descriptions and who are constantly afraid that our pretence to science will be discovered:

> "…We worry that by sticking to description there may be something missing, since we have not 'added to it' something else that is often

[12] It can be recognised that this chapter also contains some rather long citations. Again, this is a deliberate move in order for me to show the original sources as well as my translations of them (in the ANT sense of the word).

[13] However, deep down inside of me, there is a positivist residing. He wants clear answers, preferably quantified and even better if presented with an error margin. He tells me that the research presented in this thesis is unscientific. It lacks the validity, the accountability and the operationality that designates decent science. At times he has had the upper hand and created a feeling of uncertainty about the value of this contribution. He has shouted that I should instead focus on a statistical model if I really want to go into this "social science mud" at all. Although at times he has halted the process, I think I have managed to convince him that something useful can come out of the approach employed in the thesis.

> called an 'explanation'. And yet the opposition between description and explanation is another of these false dichotomies that should be put to rest – especially when it is 'social explanations' that are to be wheeled out of their retirement home. Either the networks that make possible a state of affairs are fully deployed – and then adding an explanation will be superfluous – or we 'add an explanation' stating that some other actor or factor should be taken into account, so that it is the *description* that should be *extended* one step further. If a description remains in need of an explanation, it means that it is a bad description" (p. 137).

Although comforting, it also means that every researcher involved in the game of description needs to take descriptions seriously and abstain from jumping to some grand theoretical reservoir to find the "true" explanations. Care must be taken to make the description into an explanation in itself.

> "Actor-networks do connect and by connecting with one another provides an explanation of themselves, the only one there is for ANT. What is an explanation? The attachment of a set of practices that control or interfere on another. No explanation is stronger or more powerful than providing connections among unrelated elements, or showing how one element holds many others. This is not a property that is distinct from networks but one of their essential properties (Latour 1988b). They become more or less explainable as they go and depending on what they do to one another. Actors are cleaning up their own mess, so to speak. Once you grant them everything, they also give you back the explanatory powers you have abandoned. The very divide between description and explanation, hows and whys, blind empiricism and high theorizing is as meaningless for ANT as the difference between gravitation and space in relativity theory…By tying the explanation to the network itself, ANT does not abandon the goal of science since it shows that this goal has never been achieved, at least through the epistemological myth of explanation. ANT cannot deprive itself of a resource it shows how no one had ever had in the first place. Explanation is ex-plicated, that is unfolded, like gravity in Einstein's curved space, it is still there as an effect but it is now indistinguishable from the description, the deployment of the net" (Latour 1997), pp. 375-376.

I have nevertheless chosen to include an analytical chapter after the empirical part, a chapter where the empirical material from both descriptions is compared. However, this part is not about explaining the findings in the case from some theoretical reservoir. Instead I propose some local generalisations - in other words, concepts that can travel. This is similar to the distinction between substantive and formal theories when following Glaser and Strauss' (1967) notation. Substantive theory is developed for an empirical area, while formal theory is concerned with conceptual areas. Formal theories can be used to "discover substantive theory relevant to a given substantive area, ...[while] substantive theory in turn help to generate new grounded formal theories and to reformulate previously established ones." (p. 34). Formal theory is thus on a higher level of generality and is produced by developing concepts and theoretical constructs that are able to 'travel' (Andersen 2004), i.e. concepts and constructs applicable to a specific situation are transferable to other situations. This should not be confused with a ranking where the ultimate goal is to find universal laws. "Generalisations are normally only valid for given classes of phenomena under given assumptions, they are concepts and theories 'of the middle range' (Merton 1967). It is a main goal for the social sciences to identify such common features that bind together and give regularities across unique variations." (Andersen 2003:10-11). Even if I find it troublesome to speak of generalisations, I do believe we can find local truths, that is, propositions that hold within defined areas.

2.5.2 Validating findings – relying on others

In their frequently quoted book, Brinberg and McGrath (1985) lay out a framework for investigating validity issues. They distinguish between three different domains in research, denoted as the *substantial* (the empirical world), the *conceptual* (the theories) and the *methodological* (the methods). Researchers have different interests and will focus more on one domain than the others. Brinberg and McGrath's point is that this has consequences for validity. The combination of different elements from the three domains restricts what can be found. In earlier versions of their Validity Network Schema (McGrath & Brinberg 1983), they identify a wide range of validity measures. They do, however, abandon this in their book and instead focus on the scope and limit of empirical findings related to the three domains. This framework could have been useful for discussing the validity of the thesis. However, validity is best ensured by following the study guidelines as laid out in this chapter and transferring them into the text, while also taking into account that validity is as relational as the rest of the world. Without an interest from the reader, the descriptions will never be looked upon as valid. Håkansson and Waluszewski (2002) formulate this excellently:

> "The five conditions [for approaching business processes] can be regarded both as basic assumptions and as main results of our study. Even if the work did not start out with an explicit formulation of these assumptions, during the process it has become more and more obvious how these underlying ideas have coloured our way of approaching the empirical world. *This means that our picture of how development takes place in an industrial setting has become more precise and detailed – but also, that this understanding is clearly based on our research concepts. If we had used other concepts we would certainly have*

> *reached another picture*. Thus, how valuable our picture is for others – regardless of whether researchers or companies – depends on the familiarity with or interest in using this or similar approaches. Again the researcher is facing the same situation as a company struggling with technological development – namely, the value of a certain solution depends on the extent to which others can relate to it" (pp. 18-19).

The message from this citation is also in perfect harmony with ANT's view on science as relying on the spread to others and is a perfect conclusion to end the discussion of everything underlying the rest of the thesis. Now it's time to get down to business.

3. Industrial production of bumpers and bumper beams: creating the Economy*

I want to investigate the aluminium bumper as an industrial product involved in order to answer the following questions 1) *What is the economic status of the bumpers?* And 2) *How has such an economic status come into being?* The answers to these questions will provide a picture of what the Economy* is and how it has changed over the last few decades. In other words, the answer will consist of the elements that the Economy* consists of and how these elements have appeared, changed, disappeared or remained.

The bumpers and bumper beams that appear in this thesis are part of a relationship between Volvo and Hydro, a relationship that has lasted almost half a century. Well, that is not completely true, as Hydro was not the name of the company that was the original participant in the relationship. The relationship was first established between Volvo and the Norwegian company Raufoss Ammunisjonsfabrikker, a manufacturer of military equipment. However, as will be made clear in the chapters that follow, the first product to be involved in the relationship was not a bumper beam and, furthermore, the production processes have changed over the years.

First, a short presentation of the history of the involved companies is presented. This is followed by pictures of the production network structures in 1970 and 1985, including the important actors, resources and activities. These pictures are contrasted to create a foundation for describing the elements that were instrumental in the period between 1970 and 1985. Then a picture of the network structure in 2006 is displayed and contrasted with the picture from 1985. Again, important elements that have contributed to changes in the actors, resources and activities are described. Thereafter, the elements that have stayed the same throughout the entire period are presented.

The chapter is concluded with a summary of the findings, a timeline outlining some of the changes in activities, resources and actors and a comparison of the economy displayed in this chapter compared to the caricature of the economy presented in the introductory chapter.

3.1 Setting the stage: a presentation of the story behind the relationship and the bumpers

The following short introduction to the "economy" part of the case is provided in order to outline some of the elements that were present prior to and at the start of aluminium bumper production at Raufoss. This includes brief details of the companies concerned and how they were involved with each other up until 1970.

From Rødfos Patronfabrik to Raufoss Automotive[14]

During the last period of the19th century and the beginning of the 20th century, much was happening in the Norwegian political sphere. Having been part of a union with Denmark from 1348 to 1814, many parties were struggling for national independence when Norway was "given" to Sweden. Even though reigned by another nation, a national constitution for Norway was written and signed on 17 May 1814[15] and a Parliamentary system was introduced in 1884. Although Norway was given freedom to implement such political measures, tension began to build up between Norway and Sweden towards the end of the 19th century and, as Norway had no separate military force, there was a concern that Sweden would use force to try to keep Norway in check. It was against this backdrop that a decision was made to set up an ammunition factory (called Rødfos Patronfabrik) at Raufoss. The location was chosen for its strategic location, which was hard to access for foreign military troops with Lake Mjøsa on one side and extensive grassland on the other. The site chosen did in fact have a few industrial buildings, including a matchstick factory that used the River Hunnelva (that runs through Raufoss) to produce energy for its production. Fortunately, the tension between the two parties never led to an open conflict and instead Norway gained its independence in 1905 – nonetheless, Rødfos Patronfabrik continued the production of ammunition after this date.

In 1917, recognising that World War I would eventually come to an end, the then manager Halvdan Bødtker-Næss began to consider the options for the factory once ammunition production reduced. Based on this initiative, a commission was formed on 22 November 1918, designed to investigate to what extent and in what areas civil production at Raufoss should take place. One of the options was to make roll bearings and the commission started negotiations with the Swedish roll bearing company Svenska Kullagerfabriken (SKF). A deal was agreed whereby SKF committed itself to purchase 500 roll bearings per day from the production site at Raufoss. In

[14] Most of the early industrial history at Raufoss is taken from Wang (1996).

[15] Although it was uncertain whether it was this document or the version signed on 4 November that was the actual one (Brekke 2005).

addition, a manager and ten experts from SKF were placed at Raufoss' disposal in the start-up phase. However, it subsequently became clear that the financial deal clearly benefited SKF most as, although production started on 1 July 1921 and increased from 71,415 roll bearings in 1923 to 199,000 roll bearings in 1925, the factory made a loss. As a result, although the initial contract period was set to end on 30 June 1926, it was cancelled in 1925.

In parallel, Raufoss Ammunisjonsfabrikker (RA) (as the company was called from 1924) tried to make their own assortment of roll bearings, independently of SKF, but only small batches were sold and when SKF lowered the prices on the Norwegian market by 70%, RA soon ran into financial trouble. As a result, the Norwegian government decided to stop production of roll bearings, providing 1.25 million Norwegian kroner to cover the loss in 1929. Overall, the roll bearing adventure almost put an end to industry at Raufoss and, indeed, the whole period between WWI and WWII was extremely difficult financially. However, during this period, many production choices were made that have contributed to the future direction – for example, the toolmakers were gathered in one tool department in 1929 and casting of aluminium alloys started with low volumes in 1935.[16]

Volvo and car production[17]

The first Volvo car rolled out of the Hisingen factory in Gothenburg on 14 April 1927. This date is recognised as the company's birthday, although work on the car had started earlier with 10 test models having already been built at the Galco factory in Stockholm the previous year. Assar Gabrielsson and Gustaf Larson, the founders of Volvo, had both worked at SKF from 1917-1920, when Gustaf Larson left to work as a technical manager at Galco. Gabrielsson, who worked as the sales manager at SKF, was an economist with good connections in the banking industry and was aware of how Swedish-made roll bearings could compete on an international market.[18] Larson was the engineer, with excellent knowledge of the automotive industry.

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[16] As an aside, it should be mentioned that two cars, or rather motorised sledges, with an all-aluminium body were produced at Raufoss in 1924, developed by the engineer H. Chr. Bjerring. They were actually some of the first cars ever produced with an aluminium frame. The test models showed great characteristics on Norwegian roads, but as Bjerring’s company Autoslede A/S went bankrupt, the production was put on a hold.

[17] The information in this section is mostly found in Lindh (1990) and Olsson & Moberger (1995)

[18] SKF is the very same company for which Raufoss was producing roll bearings in the 1920s

On 19 August 1926, Gabrielsson and Larson met with managers from SKF and, as a result, AB Volvo was established with Gabrielsson as the manager.[19] SKF granted the new company a loan of 2 million SEK to start production of a series of 1000 cars, 500 as convertibles (ÖV4) and 500 with a complete body (PV4). They planned to produce and sell these during 1927, with 400 cars earmarked for export. It was then planned that production would increase to 4000 cars in 1928 and 8000 in 1929. The sales of passenger cars were, however, lower than expected and Volvo made a loss until November 1929, at which point they began to make a profit. This improvement in the company's financial position from 1929 onwards was mostly due to the profits from a series of lorries that they started to produce in 1928. In fact, the production of ÖV4 and PV4 never extended beyond 1000 vehicles, although it came close with a total of 996 over the period 1927-1929. In the context of this thesis, it should be noted that a "special" version of PV4 was released in 1928 and this version had bumpers as standard equipment both in the front and the rear. After five years of continuous profit, Volvo shares were launched on the Stockholm stock exchange in 1935.

A sales handbook was given to every Volvo sales outlet in Sweden in 1936. The authors were anonymous, but it is generally considered that the handbook was written by Assar Gabrielsson, except for a technical chapter probably written by Gustaf Larson. The technical chapter starts with the paragraph:

> "An automobile transports, and is driven by, people. Thus, the basic principle for all construction work is and must be: safety." (Volvo 1936, my translation)

This citation was largely employed when constructing safety as a core value in the Volvo organisation and it is still to be found on the Swedish Volvo's homepage, clearly demonstrating how dedicated Volvo has been to safety since its early days.[20]

1949 was the first year (since 1927) when more cars than lorries were produced, even though a few more years passed before the profit from passenger cars exceeded the profit from lorries. One of the trickier sales arguments was the "PV warranty" issued in 1954. The warranty, which was included in the sales price, meant that every buyer of a PV 444 would be compensated for all damage on the car exceeding 200 SEK for a five-year

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[19] The name Volvo was a registered trademark as early as 1915. It is the Latin word for “I roll” and was initially used for a new series of roll bearings.

[20] http://www.volvocars.se

period. Unsurprisingly, Swedish insurance companies reacted poorly and issued a formal complaint against Assar Gabrielsson, who was accused of breaking the insurance law and for conducting an insurance business without a permit. The complaint made it all the way to the Supreme Court where the "PV warranty" was finally declared legal in 1958. Advertisements were being published where Volvo owners smilingly told their stories about how they had wrecked their cars and later picked up a new one for only 200 Swedish Kronor. When the first warranties expired in 1959, Volvo was granted a permit to set up an insurance company (Volvia) where Volvo owners could sign up to continue their warranty (Olsson & Moberger 1995).

During most of the first 30 years of the company's life, most of Volvo's exports were made to countries that had no car production; however, in 1955, the first attempts at entering the US market were undertaken and they gradually managed to develop a market during the late 1950s. Initially, selling Volvos in the US automobile market was likened to "selling refrigerators to Eskimos",[21] but by 1962 the US had become Volvo's second largest market (after its home market) and Volvo ranked as number four on the list of cars imported into the US.

Growing sales inside and outside Sweden resulted in the need for both more production capacity and also a desire to get closer to the company's customers. As a result, the Torslanda factory was opened in 1964 (enabling Volvo to move out of the old locality of Hisingen), and a factory was opened in Ghent, Belgium in 1965. Together, these plants helped to ensure that Volvo had the capacity to meet future changes in demand.

The (first) Volvo deal

After the Second World War, the Norwegian Storting passed a law in 1947 with important changes in the regulations regarding the military industry in Norway. This resulted in the transfer of military companies from state control into autonomous industrial companies with state ownership. At the same time, sales figures had increased steadily at Raufoss at the end of the 1940s and in the early 1950s, mainly due to the continued production of defence products that were largely connected to the NATO agreement.

However, in early 1955 a committee was formed to investigate production and sales possibilities because of an expected decrease in ammunition production. The committee submitted a report in November of the same year, proposing that RA should visit Volvo and other Swedish industrial companies to further investigate the possibilities of manufacturing

[21] The Volvo club: http://www.volvoclub.org.uk/history/history_50s.shtml

components for them. It was also suggested that RA should focus on the production of aluminium profiles in a newly acquired extrusion press. In this respect, the committee recommended producing the necessary die tools and investing in a smelting oven and a casting machine. During the period the committee was doing its work, Volvo approached Mekaniske Verksteders Landsforbund (MVL), a Norwegian organisation for mechanical workshops, to search for Norwegian suppliers. In MVL's response, it suggested that Raufoss was a potential sub-contractor for car components. As a result, Volvo got in direct contact with RA, who showed great interest – but it transpired that RA was unable to compete on prices, partly due to the cost of import tariffs imposed by Sweden.

During 1956 and the start of 1957, negotiations were underway between the national governments of Norway and Sweden, Volvo and the defence industry in Norway (including RA and Kongsberg Våpenfabrikk (KV)). Nilsson (1998) concludes that it was the import restrictions on foreign cars to Norway that made the deal interesting. Under the regulations existing in 1956, countries within Europe could export 4000 cars to Norway and people in Norway had to apply for a permit to get a car. In addition to this European quota system, it was possible to get cars from Eastern Europe through bilateral agreements. As part of this process, Volvo managed to negotiate a quota of 3000 cars in 1957, despite resistance from both the Financial and Foreign Ministry in Norway. Other car-producing nations, particularly the UK, protested against the benefits given to Volvo. However, whilst they wanted higher quotas, none of the British car producers wanted to make an offset agreement that resulted in the sourcing of components with Norwegian companies. When the total Norwegian import quota was also raised, the criticism of the Volvo deal became less and less visible. The restrictions on imports were removed in 1960, but the deal to use Norwegian car components had been clearly implemented as evidenced by a press release from Volvo on 26 November 1956 that stated:

> "the Volvo deal is a long-term cooperation contract. It will not end because the Norwegian car import restrictions are repealed. The cooperation will go on." (Volvo 1956, my translation)

The production of components for Volvo had actually started in 1957, but it initially only consisted of a few components made from brass and steel, and RA delivered only small volumes to Volvo throughout the 1950s and the beginning of the 1960s. However, Bjarne Hurlen, former CEO of Kongsberg Våpenfabrikk (KV), was appointed as the CEO of both KV and RA in February 1961. He had been instrumental in negotiating the original Volvo deal and followed Volvo's expansion and internationalisation closely in the 1960s, becoming friends with Volvo's CEO Gunnar Engellau.

The beginning of bumper production

RA acquired a new 1250-ton extrusion press in 1962 to strengthen its ability to provide components for the building industry. In this respect, the company was supported by Årdal og Sunndal Verk (ÅSV) which was, at the time, a large Norwegian aluminium producer and responsible for delivering extrusion billets in aluminium (i.e. aluminium alloys with the right geometrical shape, in this case cylinders) for subsequent extrusion.

The focus on extrusion of aluminium had an impact on the relationship between Volvo and RA in the mid-1960s and this resulted in the signature on 15 July 1965 of a contract for delivery of 500,000 aluminium bumpers. The bumpers were to be produced over a period of five years starting from 1967. Volvo had previously developed the bumpers in cooperation with Svenska Metalverken (later called Gränges) and Volvo was one of the first companies to use aluminium bumpers, with the decision to go for a new material being largely connected to the aims of the designers at Volvo.[22]

The first bumpers left Raufoss late in 1966, but as the production factory was not completely finished, the first batch had to be taken to the burnishing equipment manufacturer in Germany. This was actually achieved by one of the production engineers, Ola Ivar Moen, loading the semi-finished bumpers into a VW Beetle and driving them to Neu Isenburg in Germany. There, the bumpers were burnished before the batch was to taken to Moss (in Norway) for anodising before it could head at last for its final destination, Torslanda, Volvo's assembly factory outside Gothenburg (Beck et al 2006).

However, this was a significant moment as, firstly, the completion of the first batch of bumpers marked the end of an almost two-year long hectic period since the contract had been signed in 1965. Production equipment had been ordered and installed, and an organisation was put in place to handle the new business area. Secondly, it marked a shift in the relationship between Raufoss Ammunition (RA) and Volvo. RA had become a supplier to the car manufacturer in 1957 after intense negotiations involving not only the companies, but also the governments in several nation states, including Norway, Sweden, and the UK. Thirdly, it can be viewed in retrospect as the start of a new era at Raufoss. The late 1950s and the beginning of the 1960s had seen only small production volumes, but the contract for bumpers made RA into a serious supplier to the automotive industry.

In 1968, the status of RA changed again to that of a state-owned limited company with a share capital of NOK 60 million. The idea had been to

[22] Interview with Gunnar Falck.

organise RA in a way similar to that of a private company and, as a result, to give the board both greater freedom and also greater responsibility. In the same year, RA, together with Årdal og Sunndal Verk and A.s. Nordisk Aluminiumsindustri, established a common company called I/S Aluminiumsprofiler. The company focused on extruded profiles and research in this area. As a result, the company's board soon decided to acquire a new 2,000-ton extrusion press for Raufoss, as the extruded profiles for the building industry were experiencing increasing demand and there were high hopes for increased bumper production.

3.1.1 Summary: conditions for aluminium bumpers in the relationship between Volvo and RA

The production of aluminium bumpers in 1970 was facilitated and made possible through a series of more or less conscious decisions by the two companies Volvo and RA, including the latter's decision to go for production of aluminium extrusions and Volvo's decision to use aluminium bumpers. These decisions, together with a number of others, led to the development of actors, resources and activities. The most important actors still present in 1970 were <u>Volvo</u>, <u>RA</u> and <u>ÅSV</u>. A few other actors, such as <u>SKF</u> and the <u>Norwegian government</u> had been instrumental in the earlier history of the companies, but were not as visible in 1970. The companies performed activities such as <u>developing bumpers</u>, <u>producing ingots</u>, <u>forming bumpers</u>, <u>anodising bumpers</u>, <u>negotiating contracts</u> and <u>creating strategies</u>. To perform these activities, they employed existing resources such as <u>competence</u> and <u>business relationships</u>, facilities like <u>ÅSV's cast house at Sunndalsøra</u>, <u>RA's extrusion presses at Raufoss</u> and <u>Volvo's assembly line at Torslanda</u>, and products like <u>ingots</u>, <u>aluminium bumpers</u> and <u>finished cars</u>.

Some actors, resources and activities were only present during the establishment of the relationship between Volvo and RA, such as <u>MVL</u>, <u>Norwegian import quotas</u> and <u>negotiations involving governments</u>. Their presence was no longer visible in 1970. Other actors, resources and activities were present, but their presence was not part of the everyday life of the companies. Still, the importance of some of them will rise to the surface as time passes, for instance the <u>state ownership of RA</u>, <u>Volvo's export of cars to the US</u> and <u>Volvo's focus on safety</u>.

Now it's time to look closer at the specifics of the development and production of bumpers, starting with a description of how production was undertaken in 1970.

3.2 From 1970 to 1985

The following section will try to explain how the Economy* has been produced as an effect of the production of bumpers (later: bumper beams) in the relationship between Volvo and RA/Hydro.[23] The section starts with descriptions and pictures of the production network in 1970 and 1985. Thereafter, these are contrasted and elements that were altered (i.e. inserted, removed or changed) in the network are presented.

3.2.1 Production of bumpers in 1970 [24]

Volvo had four car models in production in 1970, namely: the Volvo 122 (known as the Amazon in the Nordic countries), the Volvo 140, the Volvo 164 and the sports car Volvo 1800. The 140 series and the 164 were the only ones with aluminium bumpers and the only vehicles for which RA supplied front and rear bumpers. Svenska Metallverken and Volvo had developed the bumper as a cooperative venture from 1963 until the start of production in early 1967 and RA was producing the parts in accordance with the specification contained in the resultant drawings.[25]

The front bumper for the Volvo 140 series weighed 2.8 kg and, in 1967, had a price of NOK 43.00, but by 1970 this had risen to NOK 55.00 (which corresponds to NOK 361.65 in 2006), although this price reflected the outcome of annual meetings between Volvo and RA at which price increases were negotiated.

The aluminium alloy billets (i.e. round cylinders of the specified alloy) were delivered to RA by ÅSV in Sunndal at a cost of NOK 4.00 per kg, which included the price of ingot and a premium for smelting and alloying. I/S Aluminiumsprofiler (Alprofil), the company owned jointly by RA and ÅSV, performed alloy extrusion at Raufoss. The extruded profiles were sold at cost to the car part production division of RA. After a hardening process, the extruded profiles were bent to shape through roll forming and stretch bending. The process was cumbersome and required intimate knowledge of the machine and the materials. The roll formers from Redman Tools Ltd.

[23] Bumper beams are the metal rail behind the plastic bumpers in today's cars. The shift of the name and position (and status?) of bumpers will be treated in a later section in this chapter.
[24] The information in this section is based on interviews with Ola Ivar Moen, Thor Wang and Åge Larsstuen, plus the following literature: (Bakke 1970; Beck et al 2006; RA 1971; Wang 1996).
[25] Gränges (now Sapa), acquired Svenska Metallverken in 1969. Interview with Gunnar Falck.

were originally built for steel profiles and the operations were different when used to shape aluminium. Bumpers were then cut and graded before being polished mechanically and finally anodised electrochemically to achieve the look of stainless steel. Throughout production, the bumpers were manually transported between the different workstations. The total cost of the processes involved was approximately NOK 37.00 per bumper, leading to a cost of production per bumper of NOK 48.00 (compared to the sale price of NOK 55.00).

The RA division that was responsible for producing car parts had Volvo as its only customer and a turnover of NOK 19.5 million in 1970, which contributed to about 5% of RA's total turnover. The rest of RA's turnover was mainly based on defence products, together with a small portion from the production of extruded profiles for building applications.

Meanwhile, RA and ÅSV were working intensively on researching and developing new alloys for bumpers. Volvo had a huge success with the 140 series, and Gränges (the successor of Svenska Metalverken) and RA did not have sufficient capacity to meet the demand. However, although there was fierce competition for the additional capacity, RA was chosen and invested NOK 4 million in a new production line, which was finished in Autumn 1970.

The bumpers produced by RA were packed in closed pallets with protective insulation between each bumper and sent to Torslanda by train. Volvo paid for the transport. At Torslanda, rubber strips produced by Forsheda Gummifabrikk and Mjøndalen Gummivarefabrikk were fastened to the bumpers and they were then manually mounted on the cars with eight screws.

The sales price in Norway in 1970 for the cheapest car in the Volvo 140 series (Volvo 142 with four cylinders and two doors) was NOK 32,680, rising to NOK 46,300 for the Volvo 164 with six cylinders and four doors. The cost of the bumper for Volvo was therefore somewhere in the range between 0.12 and 0.17 percent of the sales price in Norway. Figure 3-1 shows an overview of the actors, resources and activities involved in bumper production in 1970.

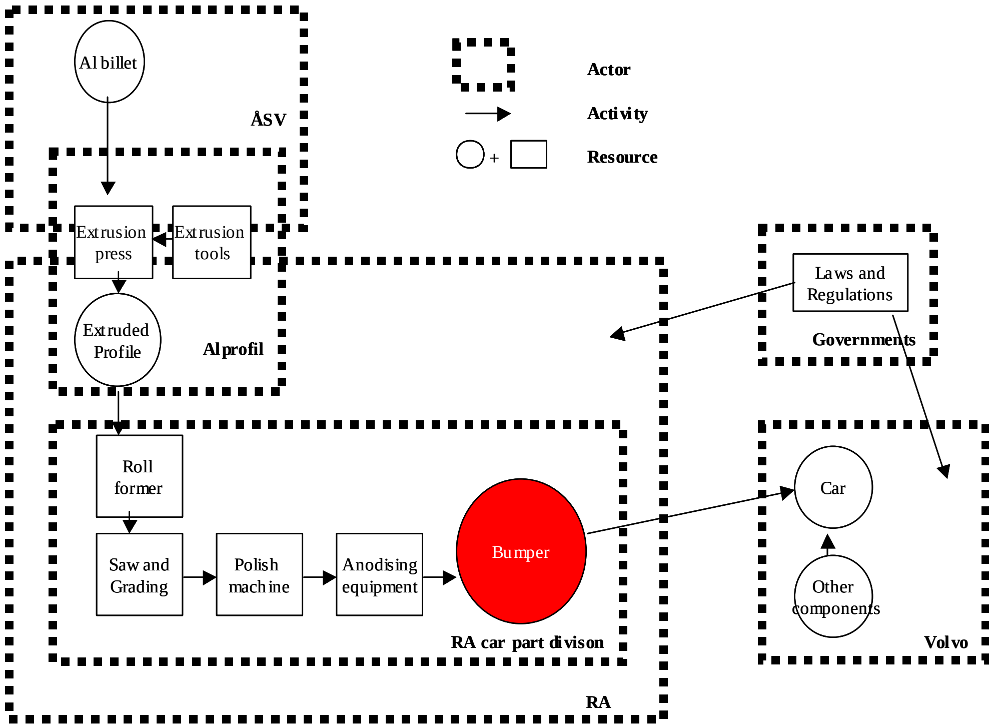

Figure 3-1 Activities, resources and actors involved in producing bumpers for Volvo from Raufoss in 1970

The above diagram is somewhat complex because of the organisational structure, with RA and ÅSV sharing ownership in the company Alprofil, but apart from this, the system for production was linear in approach and was as shown above.

There are of course other actors (having additional resources and performing additional activities) involved (for instance) in supplying components for machinery. Changes in the network surrounding the companies directly involved in producing the focal resource will most likely be captured when the picture of the network from 1970 is compared to more recent ones (i.e. 1985 and 2006). If the changes are not captured, they are probably not important for the production of the Economy*.

Now let us jump to 1985 and see what production looked like at that point in time. This will give us a picture of the production network that can be compared to that from 1970 and form a basis for describing the change of elements (and thus the Economy*) during the time span from 1970 to 1985.

3.2.2 Production of bumpers in 1985[26]

In 1985, Volvo produced four series of car models: the Volvo 340, the Volvo 360, the Volvo 200 and the Volvo 700. The first two (340 and 360) were small family cars produced at the Volvo factory in Holland that they had acquired in 1973[27]. RA has never supplied bumpers for Volvo's series of small cars, but they were the sole supplier for the Volvo 760.

RA delivered bumpers for the Volvo 700 and 200 series. The 700-series bumpers were solid profiles covered by a painted plastic cap. The bumpers for the 200 series were aluminium beams covered by an unpainted cap, except for those still being produced for the 1975 edition of Volvo 240 which were still aluminium bumpers with a rubber strip. RA had been given increased development responsibility by Volvo a few years earlier, but the latter still undertook most of the specifications.

The price of the bumpers was NOK 175.00 for the newest Volvo 200 bumpers (those with aluminium and plastic, weighing 7.2 kg) and NOK 258.00 for the Volvo 700 bumpers (with aluminium and painted plastic, weighing 7.7 kg).

Using either new material or the output from an internal recycling smelter owned by ÅSV and RA in the joint company ALPROFIL, Årdal og Sunndal Verk (ÅSV) supplied aluminium alloy billets to the extrusion plant. The smelter at Raufoss had a larger capacity than just internal recycling and ÅSV also supplied primary aluminium to the smelter. The extrusion plant was also organised under ALPROFIL and delivered extruded profiles to RA's forming lines at cost. The cost of the aluminium (including operations) was approximately NOK 100.00 for both the bumpers, with material costs representing 50% of this.

Production of plastic caps took place at the same time as production of the aluminium beams. Statoil supplied the plastic material that was formed into plastic caps in large (1300-ton) injection moulding equipment. The cost of the plastic caps, including the production operations, was approximately NOK 40.00 for both bumpers.

After 1982, the plastic caps for the Volvo 700 series were painted at Raufoss in an automatic paint machine. The cost for painting was NOK 100.00 per

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[26] The information in this section is based on interviews with Åge Larsstuen, Kolstein Asbøll, Thor Wang, and Per Harald Sørlien, plus the following literature: (Elnæs 2005; RA 1986)

[27] The car manufacturer previously known as DAF

bumper. The final step was assembling the aluminium bumper and the plastic caps, costing NOK 10.00 per bumper.

The car parts division had a turnover of NOK 305.9 million and contributed approximately 21% to RA's total turnover, approximately 55% of the car part division's turnover originated from deliveries to Volvo.

The final bumper systems, including assembled aluminium bumpers and plastic caps, were transported to Torslanda by trucks from Toten Transportsentral A/L. Volvo paid for the transport, which was a delicate matter especially for the painted plastic caps. At Torslanda, the bumpers were mounted onto the assembled car.

The sales prices of the cars in Norway were from NOK 137,000 for the Volvo 240 and from NOK 186,400 for the Volvo 740. The cost of the bumpers for Volvo were thus between 0.13 and 0.14 percent of the sales price in Norway. Figure 3-2 shows an overview of the actors, resources and activities involved in bumper production in 1985.

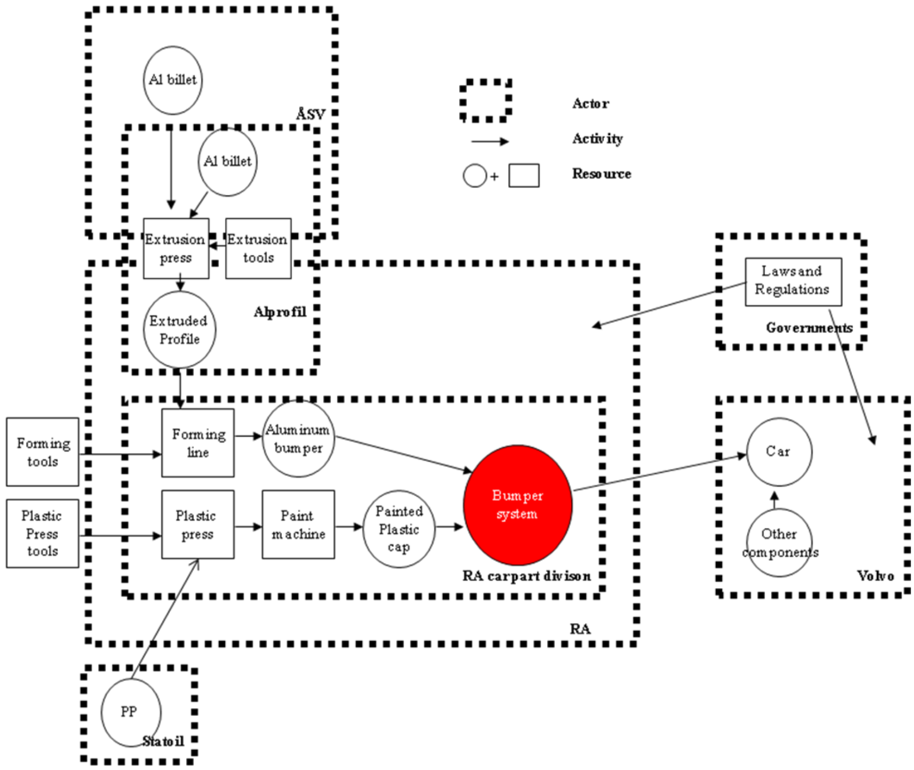

Figure 3-2 Activities, resources, and actors involved in producing bumpers for Volvo from Raufoss in 1985

Figure 3-2 shows RA having the responsibility for assembling bumper systems (consisting of aluminium bumpers and painted plastic caps) for Volvo. The material inputs to RA are provided by ÅSV (aluminium) and Statoil (plastic). The diagram only displays actors, resources and activities involved in the daily production of bumpers in 1985, not all actors, resources and activities involved in development activities or providing machinery for production activities.

3.2.3 Changes in the production of bumpers from 1970 to 1985

The short descriptions of the development and production of bumpers in the relationship between RA and Volvo in 1970 and 1985 and the diagrams displaying important activities, resources and actors from the same years are used to highlight changes in the production structure. When comparing the arrangement from 1985 (shown in Figure 3-2) with that from 1970 (shown in Figure 3-1) as presented in Figure 3-3, it can be seen that the overall process is similar with the exception of the plastic forming line, which represents a significant new feature in 1985.

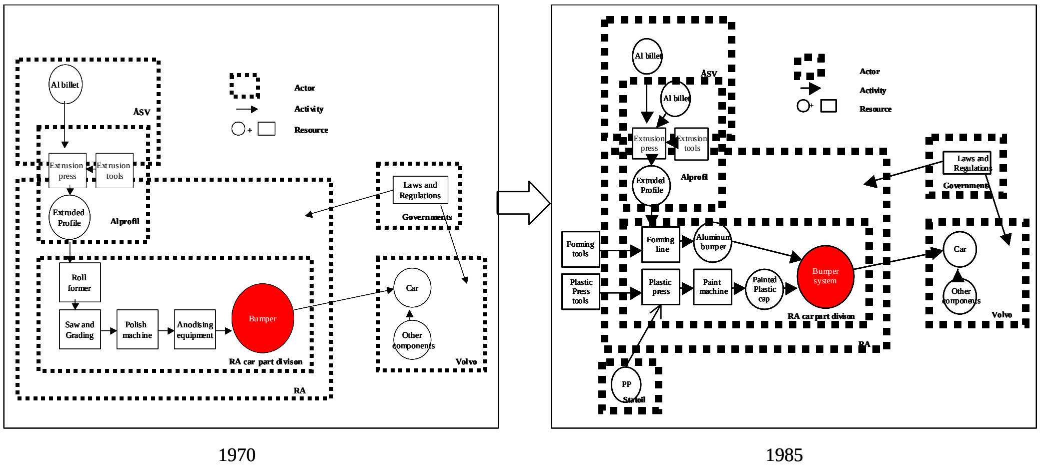

Figure 3-3 Comparison of the bumper production networks in 1970 and 1985.

Upon first glance, Figure 3-3 indicates that more resources and activities are placed inside the box delimiting the actor RA and one more actor (Statoil) is added. However, although the diagram quickly exposes any major differences in the composition of the production network between 1970 and 1985, it does not provide easy access to the actual changes in the three layers. Table 3-1 is included to unmask these changes. It shows an overview of the actors, resources and activities in 1970 and in 1985. Changes between the two years are marked in red.

Table 3-1 Actors, resources and activities present in the production network in 1970 and 1985

Layer	1970	1985
Actors	RA Alprofil Volvo ÅSV Governments	RA (automotive) RA (autoplastics) Alprofil Volvo ÅSV Statoil Governments NHTSA
Resources	Extrusion Press Extrusion tools Roll forming Assembly line Final car Aluminium alloy billets Laws and regulations Taxes	Re-smelting plant Extrusion press Extrusion tools Roll forming Plastic forming Plastic painting Assembly line Final car Aluminium alloy billet Aluminium Plastics Laws and regulations Taxes
Activities	Extrusion (profile prod.) Forming Assembly Aluminium production Law making	Development Negotiations Extrusion (profile prod.) Forming Assembly Aluminium production Law making and revising Evaluating

The table shows that there was a clear expansion in the number of actors, resources and activities from 1970 to 1985. Some but not all of the expansions are related to the inclusion of production of plastic caps at Raufoss. Those related to plastic production are activities connected to making them (such as plastic forming and painting of plastic cap), the resources needed to produce them (such as plastic forming tools and a paint factory) and the actor Statoil that supplies the plastics. Those not related to plastics include development activities at Raufoss, a re-smelting plant and the separate divisions for automotive parts in RA and NHTSA.

Changes in the product from 1970 to 1985

Something that shows in neither Figure 3-3 nor Table 3-1 is the actual content of the layers. Actors, resources and activities may, in other words, have the same denotation in 1970 and 1985, but still be quite different. This was partly revealed by the descriptions of the production process in the respective years. For instance, did the final products – the cars ready to be sold to customers – change from 1970 to 1985 and did the bumpers mounted on them also change? Changes in the cars and in the bumpers will be seen in Figure 3-4 displaying pictures of a Volvo 144 from 1970 and a Volvo 740 from 1985.

Figure 3-4 A Volvo 144 from 1970 on the left and a Volvo 740 from 1985 on the right (image from RA's archive on the left and from Volvo club on the right).

From being a small and easily overlooked part in 1970, by 1985 the bumper has become massive. For example, the metal part of the bumper is visible in 1970, while the plastic cap totally covers the aluminium in 1985. The aluminium bumper itself, though not as visible, has become heavier.[28] To accommodate such changes, activities and resources have been altered all the way from the production and composition of the aluminium ingot to the assembly of the final car. The specifics of the changes in the layers will be described in the following text to explain how elements were changed or were able to remain stable.

3.2.4 Elements that contributed to changes between 1970 and 1985

This section describes changes in some of the actors, resources and activities involved in bumper production between 1970 and 1985.

[28] It is appreciated that there are other changes in the appearance of the cars and it is not just the bumper that has become sturdier and more massive in 1985.

Safety bumpers: from reluctant materials to expanding business

The head of the RA car part factory, Bjørn Bakke (1970) stated that:

> "The rapid increase in the sale of cars is well-known. The outlook for the years ahead does not indicate any reductions in the sale – rather the opposite. The car factories are making extensive use of subcontractors, which opens up possibilities for production on a grand scale. Being able to produce high numbers of a few products is obviously a dream come true from a production point of view. Competition for winning such orders is very fierce and highly rational production is necessary to attract attention, which in turn requires significant investments."

And so they did: RA invested large sums in bumper production over the next 15 years and beyond, as will be demonstrated in the subchapters to come. However, we turn first to one of the biggest changes in the history of bumpers, which happened in 1972.

Legal requirements and test protocols

Up to 1972, there were no formal requirements guiding the design of bumpers. Insurance companies and the carmakers themselves had performed simple crash tests since the 1920s, but no standards were in place to benchmark bumper performance. Although insurance companies had an interest in bumpers, they were used more as styling elements than safety devices. The "revolution" regarding car bumpers started with the US National Highway Traffic Safety Administration (NHTSA), which issued Federal Vehicle Safety Standard (FMVSS) 215 "Exterior Protection" on 9 April 1971 (NHTSA 1971). This became effective on 1st September 1972 and affected all 1973 car models. The standard contained requirements for bumpers to withstand a 5 mph impact at the front end and 2.5 mph impact at the rear end. All car manufacturers who wanted to sell cars in the US had to comply with the standard and this led to hectic activity amongst the European (as well as American) car manufacturers. Although the OEMs were aware that such requirements would come, the long development times meant that carmakers were almost always informed well in advance before new legal requirements were enforced. About 25% of Volvo's car production was exported to the US, which was the second largest market after the home market, and the change in legislation thus had a great impact on the development of Volvo models.[29] However, RA was able to capitalise on its relationship with ÅSV in order to develop an aluminium alloy that could satisfy the requirements.[30]

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[29] Interview with Gunnar Falck

[30] Interview with Thor Wang and Kolstein Asbøll

A short detour to discuss aluminium and aluminium alloys

Aluminium is the most abundant metal and the third most common element in the earth's crust. Nevertheless, it is a fairly "young" metal both in relation to the date of its discovery, and its subsequent commercial use. One of the reasons for its late discovery is aluminium's propensity to create stable compounds with other elements, especially oxygen. This propensity is a drawback with regard to the production of primary aluminium, as a large amount of energy is needed to purify the aluminium. However, in the production of bumpers and bumper beams, the oxide layer that forms on the surface provides resistance to corrosion.[31] With a low density coupled with high strength, it was used early on in the aviation industry. However, due to its relatively high cost and the car manufacturers' close relationship with the steel industry, aluminium had not managed to penetrate the automotive industry.

Aluminium in its pure form is a soft material. The addition of other metals to make alloys changes the properties and is necessary to create strength. Alloys are classified according to an international system with four digits, from 1xxx to 8xxx depending on the alloying elements. 6xxx alloys, containing aluminium, magnesium and silicone, are the ones most frequently used in the automotive industry today and are also widely used for building applications. However, 7xxx-alloys with aluminium, zinc and magnesium are stronger, but also more expensive to produce and apply in manufacturing.

Cooperation between RA and ÅSV

The choice of aluminium alloy for the first bumpers produced at Raufoss was already decided before RA signed the contract with Volvo in 1965. ÅSV had some problems in delivering the right quality during start-up and the alloy was initially supplied by the Swiss aluminium company Alusuisse (part of Alcan, the world's second largest aluminium producer, since 2003).

ÅSV and RA were two of the largest companies in Norway. When RA decided to pursue extrusion of aluminium profiles, ÅSV was a natural partner for cooperation. ÅSV was a major producer of aluminium with a clear focus on and a strong R&D department in material technology. The company did not, however, produce much more than primary aluminium and it saw the relationship with RA as a way to gain access to a market for finished products.[32]

[31] Interview with Sigurd Rystad
[32] Interview with Thor Wang and Kolstein Asbøll

In 1968 RA and ÅSV created the joint company I/S Nordiske Aluminiumsprofiler (Alprofil) to manage the aluminium extrusion business at Raufoss. An extrusion press designed only for aluminium was purchased at the cost of NOK 10 million and started operating in August 1969 (Beck et al 2006).

Even before the FMVSS 215 was released, the companies anticipated regulation. ÅSV and RA developed an alloy in the 7000 series, originally called ÅSV 2054. Tests with the new alloy had already been performed in 1970 and this helped to ensure at the time the new regulation was implemented that RA could start supplying bumpers to Volvo for the US market with the right characteristics to meet the requirements of the standard. This was, however, not achieved by the alloy alone, as it was also necessary to almost double the wall thickness (and hence the weight) of the bumpers. This had a significant impact on the efficiency of the production process, as the stronger and heavier bumpers affected both extrusion and roll forming adversely. As a result, a large number of bumpers had to be scrapped and were piled up behind the factory[33]. The bumper was actually made in two different models; one for the US market and one with half the wall thickness (and almost half the weight) for all other markets. Figure 3-5 shows the new bumper with the strong alloy. The parallel holes on the bumper are for fastening the rubber strip. The holes at each end and in the middle are for clamping the bumper to the car.

[33] The locals called the pile “The Timber Hill” (Tømmeråsen), referring to the name of the head engineer Nils Chr. Tømmeraas. Interview with Ola Ivar Moen

Figure 3-5 The bumper for the Volvo 140 series after the development of the "strong" alloy (image from RA's archive)

Even if the costs exceeded income for the first period of production, the "safety bumper" was a success not only because it complied with the US standard, but also because it attracted other customers to the company. The oil crisis in 1973 was also convenient for the aluminium bumper beam because, although car manufacturers experienced a decline in sales, aluminium became a favoured material for bumpers on larger cars when weight and fuel efficiency became key characteristics on which design focussed.

One of the reasons why RA could not expand its business was the small organisation. In the early 1970s, they had a process organised solely to fulfil the contract with Volvo and the sales organisation was too small to handle more customers or to market the bumpers to other car producers.[34]

Although Pehr G. Gyllenhammar; newly appointed CEO at Volvo, declared Volvo's, and the automotive industry's first environmental policy at the UN

[34] Interview with Thor Wang and the following literature: (Beck et al 2006)

Conference on the Human Environment in Stockholm in June 1972, the staff at Raufoss were much more concerned with getting organisation and equipment in place for large-scale bumper production. Audi, VW, Porsche and Saab all wanted bumpers for cars being exported to the US. As a result, following an investment in equipment of NOK 33.5 million and an increase in the workforce, RA started producing 18 different variants of bumpers in Spring 1973. Wang (1996) states:

> "When manufacturing of safety bumpers started in Spring 1973, it was problems, not bumpers, that were produced."

In 1973, Volvo also finalised the development of the cars that were taking over for the 140 series, the even more popular 240 series. A lot of the cars' features were taken from the Volvo Experimental Safety Car (VESC), built in 1972 and unveiled at the Geneva Motor Show in 1972.[35] This was especially true of the front with its large crumple zones and rigid bumpers, which were continued in the 240 series. Proof of its safety was provided when NHTSA purchased a fleet of Volvo 240s to use as reference cars for safety testing.

The second Volvo deal

Pehr Gyllenhammar had ideas about Volvo being a company with more strings to its bow. He wanted both to secure Volvo's place in the automotive industry and expand Volvo's business to include other areas, initiating several projects in the late 1970s and early 1980s. An example of the first was an attempt to merge with Saab in 1977, but Saab turned down the deal. An example of the latter included talks with the Norwegian government, first the Norwegian prime minister and then the Norwegian main negotiator Jens Chr. Hauge (Borgström & Haag 1989).

Stortingsproposisjon 69, 1978-79, states:

> "Discussions about closer cooperation between AB Volvo and Norwegian authorities were initiated between Prime Minister Nordli and Volvo's CEO Pehr G. Gyllenhammar at the start of 1978. After approximately 12 weeks of confidential negotiations, the Norwegian Government and AB Volvo Gøteborg entered into a principal agreement on 22 May 1978 regarding converting AB Volvo into a Swedish-Norwegian Group and Volvo Petroleum's participation in the upcoming 4th licensing round." (Industridepartementet 1979)

35 http://www.volvocars.com/corporation/NewsEvents/News/news.htm?item=%7B1BC6607D-0567-4C97-BC25-388B24E076F9%7D

The draft of the agreement proposed to make Volvo into a joint Swedish-Norwegian company, whereby one Swedish and one Norwegian holding company were to be established which together would own a joint company with a respective ownership ratio of 60% / 40%. Jens Chr. Hauge had proposed such a structure on the basis of a model employed for the airline company Scandinavian Airline Systems (SAS) in 1951, where Hauge had also been involved in the negotiations.

The agreement proposed that the new corporation should invest NOK 500-700 million in Norway and set up a factory for car production. This was supposed to create between 3000 and 5000 jobs in Norway. As a quid pro quo, Norway would grant Volvo access to Norwegian petroleum reserves. There were also commitments for Norway to secure the supply of oil to Sweden, i.e. not to Volvo as a company but to Sweden as a nation.

However, there was opposition of both sides of the border. The leader of the Norwegian conservative party, Kåre Willoch, was sceptical as to whether Volvo had such a prosperous future as a car manufacturer. On the Swedish side, the powerful industrialist Marcus Wallenberg personified the opposition. He said of Gyllenhammar's initiative:

> "He [Gyllenhammar] should only know what job we had with SAS. Working over the border with the Norwegians, I don't think he knows what he sets off to." (cited in Olsson 2000, my translation)

The main arguments were, however, connected to doubts about the value of the Norwegian contribution to the agreement.

The Norwegian Council of State approved the final agreement on 15 December 1978, but we will never know whether the Norwegian Parliament would have approved it because before it reached that stage, the Swedish shareholders (including an organisation of small savers opposed the deal), voted against it in the general meeting. This was probably due, at least in part, to the fact that elements of the deal were directly between the Swedish and the Norwegian government instead of providing direct advantage to Volvo as a company.[36]

Even though the Swedish shareholders turned down the deal, it did not end up totally without consequences. As a direct outcome, a project on new materials in cars was started, with RA as one of the main contributors. The project was sponsored by the Royal Norwegian Council for Scientific and

[36] Gyllenhammar eventually got involved in the oil business by acquiring the investment company Beijerinvest in 1981.

Industrial Research (NTNF) for Volvo and was carried out in 1978 and 1979. Several people at RA were involved in the study, which looked at future trends for lightweight materials including aluminium, plastics and magnesium in cars.

Introducing plastic: a new string to the bow or a complementary material?

The material project discussed above may well have been the first introduction to plastic for RA's car part division. Although some plastic items were already manufactured within RA, this was at the other end of the scale with small objects such as keys for typewriters, which had totally different requirements and used different materials to the plastics needed for the exterior of a car. More broadly, Renault had introduced the first plastic caps in 1971 and several OEMs started using them during the 1970s.[37]

In 1977, Volvo decided to use a plastic cap covering the bumper on the new version of the Volvo 242. The aluminium bumper systems between 1972 and 1980 had been strong and had performed well, but they were starting to become heavy (for example, bumpers for the US market could weigh up to 10 kg), costly and with few opportunities to enhance the cars' styling. In addition, the combination of the aluminium bumper and the rubber strip had created some problems with galvanic corrosion.[38]

Three companies were evaluated as possible suppliers: Plastal, Viking Mjøndalen and RA. Although RA had no technology and no organisational competence, they were chosen as a supplier because of several reasons. These included:

- A good relationship to Volvo with personal relationships on several levels in the organisations
- Knowledge of cars and the automotive industry
- A will to succeed and make necessary investments (e.g. as shown in the build-up of developmental capabilities)
- The close connection between the aluminium bumper and the plastic cap, which created a greater need for production coordination than with the bumper and the rubber strips
- The possibility of creating lightweight solutions for other components in the body and chassis using combinations of aluminium and plastics

[37] Interview with Per Harald Sørlien
[38] Interview with Sigurd Rystad

RA's decision to expand into production of plastic caps was probably connected to an expectation that it was an important move to keep a good relationship with Volvo (Elnæs 2005). Of equal importance was the close relation between RA and Statoil, the Norwegian state oil company, which could supply plastic raw material. Jens Chr. Hauge was the first chairman of Statoil and was a member of the board of RA. Statoil, RA and KV even shared their main office in Oslo, and Statoil invested NOK 50 million in RA to increase competence in plastics and aluminium in the 1980s (Elnæs 2005).

Between 1979 and 1980, NOK 30 million was invested in production equipment and two people expert in the production of plastic components were brought in from Skriver Industries. As a result, RA was ready to deliver plastic caps from 1980. The facelift of the 240 series included the introduction of an unpainted plastic cap, making the bumper a more integrated and less conspicuous part of the car. The testing and start of production went well, even if the process was cumbersome due to extensive manual handling:

> "Among other things, the removal of tools and machinery was all done manually. Even if the 1300 ton machines were dwarfed by the subsequent 3000 and 4000 ton machines, they were fairly awkward and heavy when you had to reach in from the outside and remove the cap without scratching or damaging the surface in any way. The tool was more than 2 metres wide and the opening in the machine was not much bigger . The surface was still warm and soft and extremely prone to scratching – it basically could not be touched at all without leaving a mark. The cap was carefully lifted out, placed on a trestle and the inlets were cut off with a knife by hand. The cap was then placed on a trolley in order to be transported to the assembly." (Elnæs, 2005)

Automation increased in later years, but not without problems and need for manual intervention.

Although the bumper in 1980 had an unpainted plastic cap as shown in Figure 3-6, the first painted plastic caps had been implemented by 1982 with the introduction of the new Volvo 760 GLE.

Figure 3-6 Volvo 240 with unpainted plastic cap

In 1982, new investment had to be made and new problems occurred as a result of the launching of the 700 series from Volvo with painted plastic caps. Although Volvo was experienced in lacquering and had facilities that could accommodate cap painting, it was convenient to have the bumpers completely finished before direct delivery to the assembly factory. Another significant factor was that Volvo was close to exceeding the emission permit from their paint factory. Although production of plastic caps differs from the production of aluminium bumpers, these two types of production are still more similar to each other than either is to painting. While care was needed in the handling of aluminium bumpers and plastic caps, it was nothing compared to the taut requirements of the painting process. An environment free from dust and oil is hard to maintain in a production site and, in addition to new equipment and a specialised building with good ventilation, the most important aspect was to change the attitude of the workers toward a perfectly clean environment.[39]

Given the strict finish requirements, transportation of the painted caps was a delicate matter. In a report from the board in 1984, the management at RA explains that there is a need to situate production closer to the car assembler. They even stated that this could be achieved by 1988-89 (RA 1984).

RA's investments in plastic cap production and gradually increasing responsibility for development issues were instrumental in the negotiation of a new long-term contract with Volvo, signed in 1981 and granting RA the role as single supplier for all bumpers that were supplied to Volvo.[40] Volvo also wanted RA as a development partner, requiring RA to keep up to date on trends in bumpers and materials.

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[39] Interview with Per Harald Sørlien and the following literature: (Elnæs 2005)
[40] That is, of the larger Volvo makes. The small Volvo 343 built in the Netherlands had steel bumpers.

One of the first results, which was also connected to the report on lightweight materials in 1978, was the experimental vehicle Light Component Project (LCP). The bumper, the plastic cap and the foam in between were developed by RA and had great energy absorbing characteristics, which made it possible to integrate the bumper into the body. This bumper pointed towards the solution that would be used in the early 1990s for the Volvo 850 (Elnæs 2005).

The business was still mostly connected to aluminium

In October 1972, the US Congress enacted the Motor Vehicle Information and Cost Saving Act (MVICS Act) that required manufacturers, amongst other things, to ensure a bumper standard that incorporated the:

> "maximum feasible reduction of costs to the public, taking into account the cost and benefits of implementation, the standard's effect on insurance costs and legal fees, savings in consumer time and inconvenience, and health and safety considerations" (NHTSA 2004)

The MVICS act concluded in 1981 that the most beneficial limit was 2.5 mph for both front and rear bumpers and the change was incorporated in the new legislation: 49 CFR, Part 581. Congress also specified the components on the car that were supposed to work after a low-speed crash – for example, the car should still be driveable and lighting should still work (NHTSA 2004). As a result, the staff at Raufoss was concerned that their customers might choose other suppliers and possibly switch to steel bumpers because if the required specification was reduced, the difference between the weight of a steel bumper and an aluminium bumper would also be reduced. There was therefore a sense of relief when some states upheld the 5 mph requirements and this resulted in car producers having to supply parts of the US market with the more rigid bumpers.

After the introduction of plastic caps, it may appear that the business at Raufoss completely changed direction and that the production of bumpers was ignored. Certainly, the Annual Report from 1982 gives hints that such worries actually existed:

> "A repositioning to other materials may force their way through in the longer term, but changes in styling requirements where the bumper reinforcement bar is placed closer to the body may still make aluminium competitive as a reinforcement bar." (RA 1983)

However, plastic caps were only delivered to Volvo and were more associated with costs than income; meanwhile, aluminium bumpers for other car manufacturers remained a profitable business. During the 1970s, important investments were made, e.g. in a cast house in 1974, in two new extrusion presses in 1973 and 1978, and in more efficient forming lines in 1976.[41]

The first cast house was built in 1974 and started production in May 1975 with a yearly capacity of 8,000 tons per year. It was built to carry out re-smelting and already had a large input of raw material from the aforementioned "Tømmeråsen". After an upgrade in 1982 when the induction oven was rebuilt to be gas fired, the cast house was able to produce 12,000 tons per year using 3 shifts per day. Even with a cast house situated at Raufoss, ÅSV upheld production of aluminium billets in the 7000 series, as RA was not self-sustained.[42]

The fact that the business was still focussing on aluminium can be demonstrated by the plans and the work done to merge RA and ÅSV. They had loosely talked about closer connections and, of course, ÅSV's CEO, Håkon Sandvold, had a place on RA's board, whilst Bjarne Hurlen had a place on ÅSV's board. The labour union at RA took the initiative and sent the Minister of Industry, Finn Kristensen, a letter on 22 October 1980 in which they expressed a desire to coordinate the Norwegian aluminium industry. The letter took the board in both companies by surprise, but after some discussion they agreed that it was in fact a good idea.[43] Jens Chr. Hauge (again) was responsible for drafting an agreement and after only six months, on 24 April 1981, the Department of Industry issued Stortingsproposisjon 131 for a merger between ÅSV and RA. The advice was that "a merger between the two companies will make it easier to realise both companies' goal to continue expansion of aluminium processing on a profitable basis" (Justisdepartementet 1982). The parliament approved the merger on 10 June 1981, to begin with effect from 2 January 1982. During the autumn, a lot of management resources were spent on the necessary preparations. However, the same autumn brought an election where the Conservative party came into power to replace the Labour party. One of the new Prime Minister Kåre Willoch's first acts was to abort the merger and when a new vote was subsequently held, the majority in the parliament voted against the proposal (Wang 1996).

Perhaps RA should be happy that the merger never took place, as the aluminium industry faced a heavy recession in the early 1980s and ÅSV incurred significant losses. To survive, ÅSV sought mergers with several other aluminium companies and a solution was eventually reached in 1986,

[41] Interview with Sigurd Rystad
[42] Interview with Roger Kyseth
[43] Interview with Thor Wang and Kolstein Asbøll

although this was a little painful for the company. However, before we look at this solution, with its huge consequences for both RA and the bumpers, we will consider how production of bumper beams was undertaken in 2006 in order to compare pictures of the production network structures from 1985 to 2006. Let us first summarise the important elements at play between 1970 and 1985.

3.2.5 Summary: important elements connected to bumper production between 1970 and 1985

There is little doubt that if one were looking for a pivotal moment in bumper production at Raufoss, the introduction of the safety bumper in 1972 would make the top of the list. This product (i.e. resource) tightened the relationship between RA and Volvo and between RA and ÅSV, it paved the way for several new customers for RA and it led to the introduction of several changes in activities and new resources. The introduction of the safety bumper would not, however, have been possible without actors, resources and activities that were already present in 1972. These include the relationship between RA and Volvo and the relationship between RA and ÅSV, knowledge of aluminium alloys, an extrusion press, forming tools, research and testing. Not to forget the Federal Motor Vehicle Safety Standard (FMVSS) 215 and its content specifying the requirements for bumpers and the issuer of the standard – the US National Highway Traffic Safety Administration (NHTSA).

The next major change came with the introduction of the plastic cap, which added new actors, resources and activities to the industrial network such as Statoil, plastic forming tools and the activities needed to make a plastic raw material into a plastic cap. Resources and activities needed to paint the plastic caps were also included later at Raufoss. Although there were additions to all layers, some resources and activities also disappeared, as the bumpers no longer needed to be anodised.

In addition to the modification, addition or removal of activities, resources and actors that were directly related to the safety bumper or the plastic cap, other changes came into play in the various layers. A re-smelting plant was set up at Raufoss and a new extrusion press was acquired. The negotiations between Volvo and the Norwegian government concerning Volvo's expansion into other business areas showed that the Economy* was not only confined to the bumper-related activities at Raufoss.

To enable us to describe the element changes in the bumpers' industrial network (i.e. the Economy*) from 1985 to 2006, let us first take a look at the specifics of the development and production of bumper beams in 2006. This description will be compared to the description of the network in 1985 to highlight those changes that have taken place.

3.3 From 1985 to 2006

In the following section, the changes from 1985 to 2006 are described. As for the period from 1970 to 1985, the presentation starts with a description of how development and production was undertaken at the end of the period, in 2006. This is followed by a picture of the production network in the same year. Thereafter the picture is compared with that of 1985 and actors, resources and activities that are different between the two years are highlighted. This is used as input for a description of how elements have changed between 1985 and 2006.

3.3.1 Production of bumper beams in 2006[44]

Volvo has constantly worked on making new car models or updating already existing models through so-called "facelifts". Thus at the end of 2006, Volvo was producing 9 different models, of which 5 were produced at Torslanda outside Gothenburg, with their bumper beams being supplied from Hydro at Raufoss.

It typically takes three years from the start of car model development to the start of production (SOP) and a car model is usually produced for six years with a "facelift" midway through its life. Whenever a new project is initiated (be it a new car model or a facelift), the first tasks involve setting a timetable for when different phases must be finished and inviting suppliers to submit proposals for systems to deliver. The SOP is the ultimate yardstick and reaching it is seen as the most important economic goal. Failing to reach SOP is seen to have dramatic consequences, as the car must be presented at industry fairs. All suppliers must be qualified by Volvo and this process comprises technical / financial investigations and evaluation schemes similar to those developed by Ford. Hydro Raufoss is one such qualified supplier and is normally invited to propose a bumper beam for new car models. The technical departments at Volvo, together with the purchasing department, carry out supplier selection for the different components / systems.

[44] The information in this section is based on interviews with Bjørn-Anders Hilland, Tobias Svantesson Kåvik, Kolstein Asbøll, Grete Valheim, Peter Holmén, Tony Wickström, Anita Lindberg, Roy Jakobsen and Martin Weiman.

When Hydro is selected as the supplier, the development of bumper beams is performed in cooperation between a Hydro development department situated in Oslo and the unit responsible for the front end of the body in Volvo. In other words, Hydro is responsible for designing a bumper beam with the right characteristics within a designated space; while draughtsmen at Volvo provide details about where the bumper beam has interfaces with other components, such as fastening brackets and holes for electric wires or air inlet to the engine. Most of the development work is done on computers, both for drawing and for simulating the bumper beams' crash behaviour. The development is financed by Volvo, i.e. a lump sum is agreed to cover all the work needed to get the drawings right and for making the tools.

The purchasing departments in Volvo and Hydro agree upon the final price of the bumper beam. An assigned team in Volvo investigates the technical processes and makes a cost evaluation. A small profit is added to the total costs and a price reduction is often included in the contract, as production is expected to become more efficient with experience. In 2006, bumper beams to Volvo comprised about 10% of the total sales from HAST at Raufoss, amounting to more than NOK 120 million.

In parallel with the development work, preparations are made for production at Raufoss. Production is connected to three important facilities: the cast house, the extrusion plant and the forming line. The facilities are organised under three different organisations, here referred to as Hydro Aluminium Metal Products (HAMP) for the cast house, Hydro Aluminium Profiles (HAP) for the extrusion plant and Hydro Aluminium Structures (HAST) for the forming line.[45] HAST is also responsible for the development department in Oslo and for creating an efficient supply chain between the activities at Raufoss. However, the three units have to maintain their own accounts, contributing to the gains or losses in different sub-units in the larger Hydro Aluminium.

The cast house produces aluminium alloys in the 7000 series. The series number designates the alloying elements that are mixed with aluminium. The 7000 series includes the addition of zinc and magnesium, with strong alloys that are not used for a wide variety of applications. That means there is a small market consisting of rather specialised products and subsequently only a small amount of recycled material to buy. Metals are purchased at Raufoss and, while all the alloying elements are bought from specified suppliers, the

[45] The organisation map in Hydro is constantly revised and the names given here do not exactly mirror the organisation at a given point in time. In fact, three of five extrusion presses at Raufoss are owned by HAST, but the equipment and the workforce are rented to HAP.

aluminium is bought on the London Metal Exchange (LME). One of the most important points in the contract negotiations is to specify the price of the aluminium, as this constitutes almost 40% of the total cost of each bumper and is constantly changing. Different contracts can be made at LME, and choosing the right one with the right amounts is an area of risk where Hydro can earn or lose money.

The output from the cast house is billets for extrusion. HAST buys the billets from HAMP and purchases extrusion services from HAP. Not all the billets are used for extrusion at Raufoss. Some of them are transported to other places where Hydro produces bumper beams, e.g. France and the USA. This makes it possible to seek economies of scale in the casting process.

In the extrusion plant, three extrusion presses are used to squeeze the billets through a small opening to produce hollow profiles. So-called "die tools" in the opening are used to produce different shapes. The tools are manufactured in hardened steel by specialist companies. Robust tools that do not need to be changed all the time are a prerequisite for efficient and economic production. Profiles are cut to the approximate length of the final product and stored in an intermediate location before they reach the forming line. The three presses differ in terms of their pressing power and the diameter of the hollow profile, which means that some products must be made at a specific press. However, the main focus of the production planner is to ensure an even distribution on the presses. More than four shifts on one press costs much more than having three shifts on each press. The extrusion process represents slightly less than 20% of the final price of the bumper beam.

The forming line is the facility where the bumper beams attain their final shape, holes are drilled and add-ons (such as brackets) are mounted. The aluminium alloy hardens over time, so it has to be heated in an oven to remove internal tension before the profile is bent. Bumpers are bent two by two and any additional operations to be carried out at the ends of the bumper beams are completed in the forming line. If such operations are to be carried out closer to the middle or if they cannot be done in the line, the bumper beams must be moved manually to a CNC machine. When the bumper beams are finished, they are placed on pallets, where the ageing process ensures that they gain their needed strength. They are then transported to Torslanda by truck. Although Hydro is responsible for requesting the lorries from Toten Transport, Volvo pays for the transportation itself.

The bumper beams go into the body factory, which is the "first" factory at Torslanda. The body factory is almost completely automated and equipped with robots. One robot is used to fasten the bumper beam to the body and the whole operation takes about 50 seconds. From the body factory, the body with the bumper beam goes to the paint shop and from there to the assembly factory. Unlike the body factory, the assembly factory has a lot of manual workstations. Windows, doors and other components are added to the body before the "marriage point", where the chassis and the body are united. Thereafter, the bumper with foam is mounted to the front of the car and the car is programmed before it is ready to be shipped to an end customer.

Figure 3-7 shows an overview of the actors, resources and activities involved in the development, production and assembly of the bumper beam.

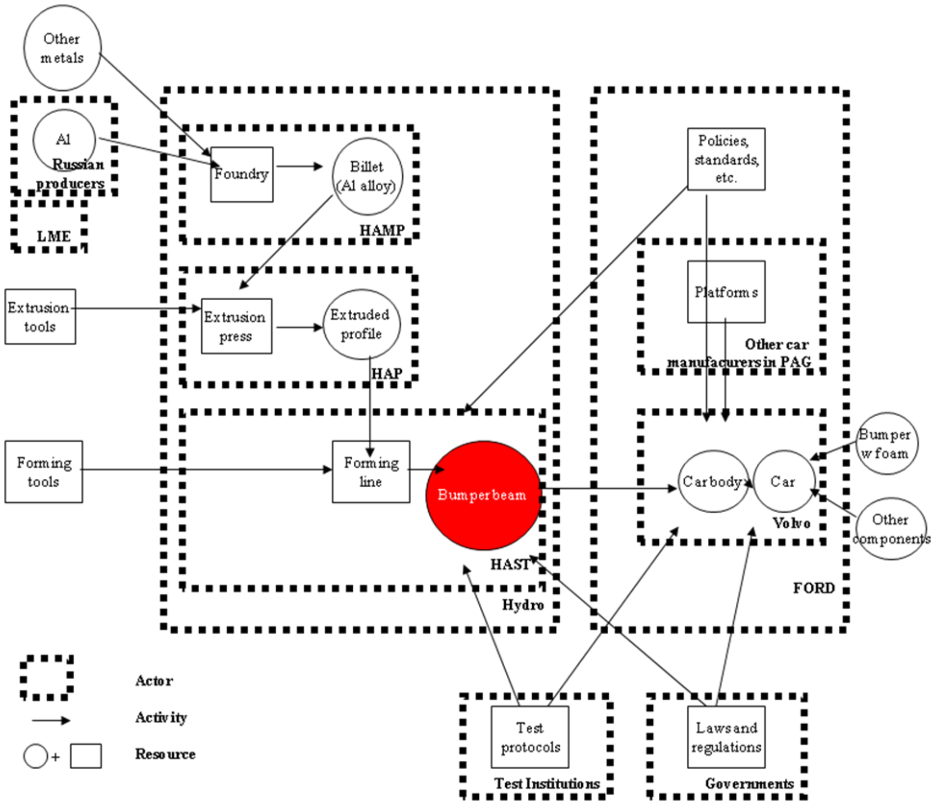
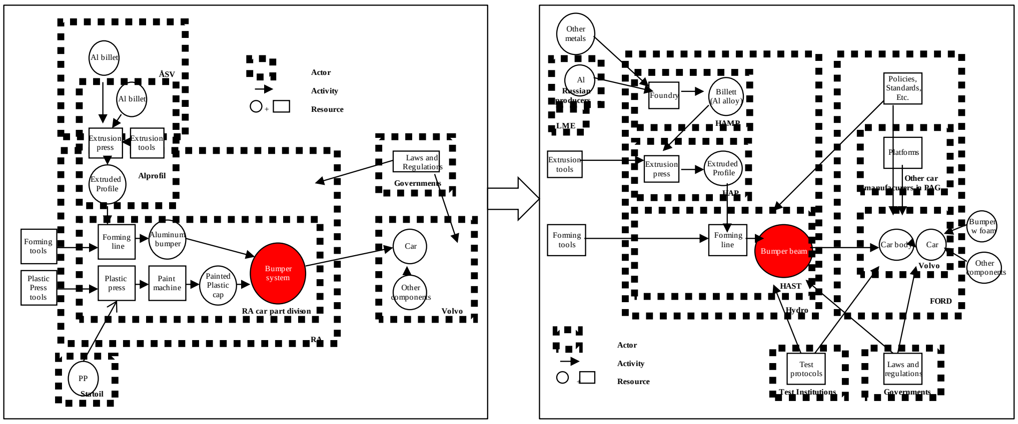


Figure 3-7 Activities, resources and actors involved in the production of bumper beams in 2006.

The diagram gives the impression that there are two large actors involved in the production of bumper beams, namely Hydro and Ford. These are, however, not directly involved in either the development of or the transactions relating to the bumper beams. Such activities take place within smaller sub-units of the larger organisations. Changes that have taken place up to 2006 are better identified when the network is compared to an earlier stage, which is the subject of the next section.

3.3.2 Changes in the production of bumper beams from 1985 to 2006

A direct comparison between Figure 3-2 (for 1985) and Figure 3-7 (for 2006), as given in Figure 3-8, shows that much has changed in the bumper production network between 1985 and 2006.



1985 2006

Figure 3-8 Comparison of the bumper production networks in 1985 and 2006.

The plastic has disappeared so the system encompasses fewer processes in 2006 than in 1985. However, the number of actors and resources seems to have increased. Ownership has become even more confusing, even if Alprofil with its split ownership is out of the picture.

To clarify the changes, Table 3-2 gives an overview of the activities, resources and actors involved in bumper/bumper beam production in 1985 and in 2006. Changes from one year to the other are marked in red.

Table 3-2 Actors, resources and activities present in the production network in 1985 and in 2006

	1985	2006
Actors	RA (automotive) RA (autoplastics) Alprofil Volvo ÅSV Statoil Governments NHTSA	HAMP HAP HAST Volvo LME Governments NHTSA EU Test organisations
Resources	Re-smelting plant Extrusion press Extrusion tools Roll forming Plastic forming Plastic painting Assembly line Final car Aluminium alloy billet Aluminium Plastics Laws and regulations Taxes	Cast house/Oven Aluminium alloy Extrusion press Extrusion tools Forming line Forming tools Assembly line Final car Business strategies from Hydro Aluminium Business targets from Hydro ASA Supplier evaluation schemes from Ford Aluminium contracts from LME Laws and regulations Taxes Test protocols Test results
Activities	Development Negotiations Extrusion (profile prod.) Forming Assembly Aluminium production Law making and revising Evaluating	Development Negotiations Raw material acquisition Smelting (billet prod.) Extrusion (profile prod.) Forming Assembly Strategising Evaluation Aluminium production Law making Evaluating Testing

The most striking difference is, perhaps, in the names of the actors; some have changed, some have disappeared and new ones are added. The resources and activities given in the table have also changed: they have increased, as was indicated by Figure 3-8. Part of this expansion is related to a change in the structure for acquiring the raw materials (the aluminium ingots) for the bumper beams.

Changes in the product from 1970 to 1985

If the visual change from 1970 to 1985 was considered to be significant, the change from 1985 to 2006 can be seen as even greater, as shown in Figure 3-9.

Figure 3-9 Volvo 740 from 1985 (left, image from Volvo club) and Volvo S80 from 2006 (right, image from Volvo cars)

The Volvos are no longer as "lumpy" as before. Although there are exceptions in Volvo's history (such as the P1800), Volvo has not been famous for its stylish design. Now the lines are smooth, which is probably one of the reasons why Volvo includes 'design' as one of its core values alongside 'safety' and 'the environment'.[46] The appealing design of the front of the car is made possible by the bumper, that is, the plastic cap has now become the bumper and is no longer just covering the aluminium beam. In fact it is fully integrated with the rest of the car, making a perfectly rounded nose from the bonnet to the wheels. Nevertheless, the aluminium bumper beam (now completely hidden) retains important structural functions for the car. The appearance of the aluminium bumper beam, although invisible, has changed quite a lot - it has become hollow and the geometry has been made more complex to accommodate less packing space in the cars. To obtain such changes, resources and activities have changed accordingly. The reminder of the case will mainly follow the bumper beam, but will pay attention to the "break-up" between the bumper and the bumper beam and the Economy* involved.

[46] The positive connotations attributed to Scandinavian design is another possible reason.

3.3.3 Elements that contributed to changes between 1985 and 2006

The time that passed from 1985 to 2006 contained a number of mergers, acquisitions and reorganisations in the actor layer and – before we forget everything about ÅSV's economic troubles – let us return to the mid-1980s to see what the solution to ÅSV's problems was.

A "merger" between ÅSV and Hydro

In 1985, ÅSV worked with the German aluminium company Vereignite AluminiumWerke AG (VAW) to explore the possibilities for integration between the companies. This initiative made Norwegian politicians force Hydro and ÅSV to the negotiating table in order to secure a strong Norwegian aluminium industry. Hydro was established in 1905 as a fertiliser producer, a production process that was closely connected to hydropower concessions. In the mid-1960s, Hydro found itself in possession of excess power and went searching for applications. The choice fell to aluminium production on Karmøy, which started in 1967. At the end of the 1960s, Hydro became involved in the search for oil, with oil and gas soon becoming the largest focus area of the company (Sagafos & Aasland 2005).

The first round of negotiations between ÅSV and Hydro did not achieve a breakthrough, but in 1986 the ownership structure was finally agreed. ÅSV was producing almost twice as much aluminium as Hydro, but Hydro's net value was set twice as high as ÅSV's because of the latter's high debt (Bergen Bank & Kreditkasse 1986). As a result of the large difference in defined value, the integration between the companies never became a merger. From the outside (as well as inside the organisations), the merger instead looked like an acquisition by Hydro. This was highlighted by the fact that the merged company was named Hydro Aluminium. It was evident that the management from Hydro was responsible for deciding the business strategy for the new aluminium company. This decision also probably reflected not only Hydro's initially larger value, but also the fact that ÅSV had twice been saved from bankruptcy by the Norwegian government in the years prior to 1986.

The ownership change had immediate consequences at Raufoss, as Hydro Aluminium did not want to continue the relationship with RA in ALPROFIL. Although Hydro was seeking opportunities for downstream operations, it did not believe in going into the automotive industry. After long discussions, the re-smelting plant stayed with RA whilst the presses were divided between the two companies. A wall was built inside the extrusion plant to separate the two companies and Hydro took over most of the profile production for the construction industry, while production of bumper profiles stayed in RA. Unsurprisingly, the workers at the factory called this divide "The Berlin Wall".[47]

Outside Raufoss, in another part of Europe, the real Berlin Wall fell in 1989. Many welcomed this fall, but for the military production at RA it became a problem. NATO's military strategies were changed and the ammunition made at Raufoss was no longer as attractive as it had been previously. This, together with the international economic recession in the late 1980s and early 1990s, meant that RA had to seek different strategies in order to survive. Volvo also suffered a drop in sales from 280,000 cars in 1987 to 190,000 in 1991 and this accentuated RA's financial problems, due to the automotive unit's major dependency on Volvo (Bronken & Tranås 1994). On 29 January 1990, when the Minister of Industry (Petter Thomassen) visited Raufoss, negotiations began for a change in RA's structure. Discussions continued in several forums during the late winter and the spring. In a parliamentary meeting on 15 of May, the decision was made to partly privatise Raufoss AS. The Norwegian state was still the largest shareholder with 53.5% of the shares. Raufoss AS became a holding company, with Raufoss Automotive as one of three sub-units (Wang 1996).

Even if the period was marked by the first decline in deliveries of products to Volvo, it was also a period where RA invested more than ever in the relationship. In 1989, one facility was set up to produce plastic caps in Uddevalla in Sweden, with another just outside Volvo's facilities in Ghent in Belgium. Each of them had an investment cost of NOK 50 million. Two years later, painting facilities were included in Belgium at a cost of NOK 90 million. The facilities ensured that RA could start "just in time" (JIT) deliveries to Volvo, reducing stock and adjusting shorter response times to the customers' needs. However, large investments coupled with low earnings led to a desperate search for cooperation partners. In 1992, Plastal invested in Uddevalla to create a joint venture with a 50/50 split; whilst production facilities for finished products in aluminium, such as ladders, construction materials and maritime products, were sold to Hydro between 1990 and 1994 (Bronken 2005).

The drop in Volvo's sales not only affected RA but also influenced Volvo itself, which searched for cooperation partners to ensure that it maintained its place in the automotive industry.

[47] Interview with Thor Wang and Kolstein Asbøll

Volvo and Renault want to merge

Volvo and Renault had founded a strategic alliance in 1990 to economise on both activities and resources. It was achieved "through a complicated scheme of cross-shareholdings, joint production and R&D agreements, and supervisory boards" (Bruner 1999).

However, as Raufoss was responsible for the development of bumpers for Volvo and Volvo thus had little in-house expertise in this area, it was natural to place responsibility for the bumpers with Renault. This decision had direct consequences for the relationship between RA and Volvo – for example, all of a sudden, the engineers in RA had to relate to new counterparts and in a language in which few were fluent.[48]

A merger between Volvo and Renault was announced on 6 September 1993 by Pehr Gyllenhammar, chairman of Volvo's board of directors, and Louis Schweitzer, chairman of Renault's supervisory board. Two new companies were to be formed: a holding company called RVC and an operating company called RVA. Joining Volvo and Renault together under a common flag would make Renault – Volvo RVA the sixth largest car producer in the world (Bruner, 1999).

But the merger never happened! Just as with the second Volvo deal, another of Gyllenhammar's prestigious projects was turned down by small savers organised through the Swedish shareholder's association (SSA). As a result, as soon as the merger was called off, the formal alliance between the companies was discontinued.[49]

However, this did not mean that the relationship between RA and Volvo immediately reverted to the pre-1990 status. New people had started working in the bumper department at Volvo and whilst the engineers at Raufoss had probably expected that everything would return to normal without their having to make an effort, it would appear that the relationship probably should have been nurtured as, in 1994, RA lost their first tender to deliver for a new Volvo.[50]

Hydro acquires RA

Meanwhile, at Raufoss there were other more pressing concerns than the loss of a single contract. It was evident that there was a need for investments in the automotive operations, but the holding company could not fulfil this

[48] Interviews with Thor Wang and Sigurd Rystad
[49] It also led to Gyllenhammar resigning his position
[50] Interview with Sigurd Rystad

need due to the difficult market conditions and some costly failed projects. The management of Raufoss Automotive had actually been on the lookout for potential partners in the aluminium section of the car part division throughout the first few years of the 1990s. Talks had been initiated with VIAG (the owner of VAW), Alcoa, Elkem and Reynolds Aluminium. None of the talks led anywhere and the last company contacted (in 1992) was Hydro through the Hydro Extrusion Group in Lausanne (Bronken 2005).

The board at RA was sceptical and the process was stopped, but attitudes changed only two years later, as RA realised that they had a significant need for investment in machinery to pursue the potential for increased growth in supply. Talks were initiated with Hydro Automotive Structures and its leader, Arvid Moss, was more understanding than the management of the extrusion group to RA's needs if it were to become a part of Hydro (Bronken 2005).

After a long round of negotiations, Hydro invested NOK 303 million in 1994, buying a 40% share in Raufoss Automotive, but the problems with financing operations were not over. The machine park at Raufoss could not accommodate the increasing production and it was soon evident that there was a need to upgrade all parts of the production process, from the cast house and extrusion presses to the forming lines. Investment was also needed in facilities for just-in-time production of plastic caps both at Torslanda and in Ghent. The capital requirement was estimated to be around NOK 900 million (Anonymous 2000).

Discussions about a possible shift of ownership continued as the mother company at Raufoss continued to struggle with its finances. It was evident that something had to happen. Hydro's acquisition of 40% had probably created a certain lock-in effect and it came as no surprise when Hydro and Raufoss agreed to make Hydro the complete owner of bumper beam production at Raufoss in 1997.

The need for investment made it absolutely necessary for RA to have a financially sound owner. Hydro certainly had the capital, but was also of such a size and with such diverse fields of interests (fertilisers, oil and gas in addition to aluminium) that a certain anxiety was present at Raufoss. Would Hydro be interested in keeping the jobs at Raufoss? Would other people be employed? Would production be moved elsewhere?[51]

However, after Hydro's takeover of RA's automotive business in 1997, not much changed immediately in the organisation. Signs were taken down and

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[51] Interviews with Thor Wang, Kolstein Asbøll and Sigurd Rystad

new signs with the name of the new company were placed on the buildings, but most of the workforce stayed the same. The largest physical changes came through investments in a new cast house and a new extrusion press. Hydro as an owner was also stricter in controlling projects. Research without contribution to the bottom line was stopped and reporting mechanisms for better control of the economy were introduced.[52]

Ford acquires Volvo

At the beginning of January 1999, Volvo was the world's smallest independent car manufacturer. Less than a month later, it was no longer!! On 28 January 1999, Ford agreed to buy the automobile division from Volvo for SEK 50 billion. The deal involved a 50/50 split on the rights to the Volvo trademark between Ford and AB Volvo. The reasons given were the high development costs associated with making new car models and a desire from AB Volvo to concentrate on manufacturing trucks and buses. Volkswagen and Fiat were also reported to have bid for Volvo Cars, with Fiat offering a higher price than Ford - but Fiat could not assure an autonomous position for Volvo Cars after the acquisition (Burt 1999).

In a press release, Volvo said:

> "Volvo Cars is a premium automotive brand and has both a strong product program and above industry-average profitability. However, over the longer term and within the context of its current position as a relatively small niche player, Volvo Cars would benefit from the economies of scale inherent in being part of a very large automotive company. In particular these would apply to the significant investments required in both the development of new car generations and in distribution." (Anonymous 1999b)

Ford made similar remarks praising the benefits of acquiring Volvo, here in the words of president Jaques Nasser:

> "Volvo is a premium automotive brand with unique appeal that represents a good opportunity to profitably extend our lineup and grow the Ford business worldwide. Volvo is a perfect complement to the Ford family of brands worldwide. Volvo has a world-class reputation for safety, quality, durability and environmental responsibility, all of which are attributes that are increasingly important to customers, and fit with our 21st century vision for Ford." (Anonymous 1999b)

Volvo was in fact about to develop a completely new platform for small and medium-sized cars, called P1. The capital required was estimated to be SEK

[52] Interview with Thor Wang and Kolstein Asbøll

30 billion and it is unlikely that Volvo could have accommodated the necessary investment. Although at the end of the 1990s Volvo presented financial results that were relatively better than Ford, the latter still had an enormous capital base through which it was in a position to finance activities such as the development or acquisition of smaller car producers. Ford itself is a conglomerate of a number of independent brands and each is given responsibility for different issues in relation to research and development within the group. Within this business model, Volvo was given responsibility for safety - not just for its own cars, but as the "Center of Excellence" for all car makes within Ford (Karlsson 2003).

As with Hydro's acquisition of RA Automotive, there were few immediate changes in the work force at Torslanda, at least in relation to the work with bumper beams. Some changes occurred in the administrative area. New reporting routines were implemented, as well as new schemes and documents for standardisation. The staff at Volvo mostly continued to perform their job as before, but the change in organisational culture was clearly revealed if there were any disagreements. For example, Ford has a much more hierarchical decision structure, with company rules and policies laid out in lengthy documents.[53]

The resultant new requirements for reporting to Ford headquarters (including the creation of formal supplier assessments) affected the relationship between Hydro and Volvo. Although the technical staff and the purchasing department could not agree on who was actually in charge of the selection process, new procedures and guidelines for the purchasing process had been put in place to ensure that suppliers were not chosen on the basis of "bribery". Ford's policy was not to accept anything from the selling organisation, not even dinners or other such gifts. The social ties between those involved at Torslanda and at Raufoss (both as RA and Hydro) had generally been quite strong. Now they had to relate in new ways and every step in the process had to be documented. Nevertheless, although outside the rules, the development engineers continue to solve problems by phone if necessary (Brekke 2006).

In addition to the change in the approach to routine work, Ford also certified all companies who acted as suppliers to brands within the group. Such certification was based both on self-evaluation by Hydro, as well as an evaluation performed by accountants and technical experts at Ford.[54]

Access to raw material creates an industry shift?

[53] Interview with head of strategy, Volvo and (Karlsson 2003)
[54] Interview with Anita Lindberg

The supply of aluminium alloy billets in 1985 was based on a combination of an internal recycling plant and a strong relationship with ÅSV, who produced billets at Sunndalsøra. The internal plant increased its output during the late 1980s and the beginning of the 1990s, but it was never able to cover the full demand for billets even though, at the end of its lifetime, it had a yearly capacity of 20,000 tons and was running with 5 shifts per day.[55]

As ÅSV was taken over by Hydro in 1986 and Raufoss experienced still greater demand, a push was created to invest in a cast house to cover the supply of aluminium alloy billets for the 7000 series. At Sunndalsøra, billets were produced for both the 6000 and 7000 series, but this meant cleaning charges had to be run in between. The extra time and cost made Hydro eager to get rid of the 7000-series production. Still, the need for extra cast house capacity was one of the reasons why Hydro invested in Raufoss. The investment in the cast house was about NOK 150 million and Hydro's financial contribution to Raufoss Automotive made it possible for the cast house to be built. Hydro was already involved in producing aluminium alloy billets - making Raufoss the production site for the 7000-series alloys freed capacity at Sunndalsøra for making the more widely used 6000-series alloys.[56]

The cast house now in use covers an area of 6000 m^2 and was ready for operation in early 1997. The capacity for the cast house is approximately 50,000 tons per year and the production rate in 2006 was approximately 40,000 tons. One batch from the oven is around 30 tons of finished billets.[57]

Casting technology has developed, especially in terms of the cleansing of hydrogen. Billets are therefore of a much higher quality than a few decades ago. During the early years of the new millennium, Hydro started production of bumper beams in France and the USA. Billets from "local" producers were tested but without satisfactory results. This may be the result of an actual difference in quality, but is also likely to be related to the extrusion technology (and the forming technology) in place at the production sites. The production set-up is an imitation of the way production is set up at Raufoss (with aid from experts at Raufoss), and may therefore be adjustable to similar billets.[58]

If the alloys are studied under a microscope, it can be seen that they have different metallurgical properties. Lower billet quality means lower

[55] Interview with Roger Kyseth
[56] Interview with Sigurd Rystad
[57] Interview with Roger Kyseth
[58] Interview with Sigurd Rystad

extrudability, which in turn means a need to run the machinery at a lower speed.[59]

Initially, the new cast house made integration between the cast house and the extrusion plant easier. If there were problems with extruding a billet, close communication between the cast house and the extrusion plant helped to ensure new casts were made without imposing too high costs, as there were short distances between the units. This advantage also made it possible to carry out test runs with small differences in alloys and/or in the set-up of extrusion tools to find more efficient combinations.[60]

The late 1990s saw many attempts to achieve a proper integrated supply chain at Raufoss, where HAST was in charge of setting the plan for billet production as well as organising the extrusion plant. In 2005, the units were again reorganised and the cast house became an economic unit under Hydro Aluminium Metal Products. Staff in HAST have since complained that integration is, once again, becoming a problem and that bumper beam production is made more difficult as a result of a decreased focus on its needs.[61]

Sourcing of aluminium

In 1985, aluminium alloys were supplied by ÅSV through the joint company Alprofil. ÅSV was responsible for sourcing the aluminium and delivering the billets. After Hydro's takeover of ÅSV, supplies still continued, but Hydro wanted to get rid of the production of billets in the 7000 series. After the building of the cast house at Raufoss, sourcing took place within HAST and there have been attempts to obtain used material for recycling.[62]

Aluminium is often praised for its excellent recyclability. Although the production of virgin aluminium[63] is energy intensive, recycling only takes 5% of the initial energy demand. There is, however, no use of recycled aluminium at Raufoss except for internal recycling. Approximately 5% zinc and 1% magnesium are used in the bumper beams - compounds that do not mix well with other applications of aluminium where silicon is most frequently used. Unfortunately, mixing silicon and zinc is like mixing cats and dogs (not a good combination!) and the resultant products are low quality if the alloys are indeed mixed. However, the situation would be

[59] Interview with Yngve Langsrud
[60] Interview with Sigurd Rystad
[61] Interviews with Roger Kystad
[62] Interview with Grete Valheim
[63] Virgin aluminium is aluminium produced from bauxite, not from recycled material.

different if bumper beam recycling could be developed, according to the former head of the HES section:

> "Hydro would be happy to accept their own bumpers in return, but require help from the customers' scrap dealer network. If something like this could be arranged, Hydro would achieve a closer relationship with the customer, while possibly including a price reduction in the contracts. It costs NOK 15-16 to alloy one kilo, whereas a scrap dealer considers zinc aluminium as "scrap" and sells it for NOK 5 per kilo. Hydro would be happy to pay NOK 7-8 and it would therefore be easy to create margins for such a project."[64]

For instance, Hydro has a shredder outside Dusseldorf that would be suitable for shredding bumper beams before sending the aluminium to Raufoss. That said, the production facility at Raufoss is not organised for using such scrap, not least because the scrap contains contaminants such as asphalt dust and oil that have the potential to disrupt the production process. There are much higher tolerances for impurities in casting than extrusion. To build up a system with re-use of bumper beams, one must approach customers (i.e. car manufacturers), insurance companies and scrap dealers – Mercedes and other expensive cars often end up in Eastern Europe where they are disassembled for all useful parts. The important issue is to control the entire chain and it must be a large-scale process, of the order of 10-20 tons per day, which puts a significant demand on the overall logistics of the operation.[65]

At the beginning of the new millennium, HAST initiated talks with a large Swedish scrap dealer to set up such a recycling system. The Swedish firm, however, demanded too high a price for the aluminium, claiming that it had German customers willing to pay such a price. HAST decided that they could not pay more than 80-90% of the LME price for aluminium, as there is often more handling and a greater loss during smelting of aluminium scrap compared to virgin aluminium. The project thus went nowhere and HAST had to rely on its normal way of acquiring material.[66]

The normal way is purchasing aluminium for the cast house on the LME. As the parent company is one of the largest producers of aluminium in the world, one would imagine that the aluminium would come from one of Hydro's production sites. However, almost 100% of the primary aluminium actually comes from Russian producers. There are several reasons for this. One is that there is a duty on aluminium from EU member states. Hydro's aluminium producing unit has negotiated a deal to be exempt from the duty,

[64] Interview with Paal Brekke
[65] Interview with Paal Brekke
[66] Interview with Grete Valheim

which means that Hydro can sell aluminium to European countries at "European prices", but it also means that Hydro at Raufoss would have to pay such a duty to buy aluminium from Hydro via the LME. With both Russia and Norway outside the EU, the aluminium from Russian producers is cheaper. Physically, the aluminium is stored in Gothenburg where LME has aluminium storage, allowing the aluminium to be transported to Raufoss in trucks that have been used to deliver plastic caps (for after-market use) from Plastal at Raufoss to Volvo.[67]

A second reason is that Hydro focuses on producing alloys, as the profit margins are larger in areas such as the construction industry than in the automotive industry. Indeed, rumour has it that Hydro have scrapped the equipment for producing ingots of the shape and size used at Raufoss.[68]

Back to the future: plastic disappears for good

In 1985, a plastic cap was attached to the bumper. A little more than 20 years later, the plastic cap has become the bumper and the aluminium, previously known as the bumper, has become a bumper beam. The bumper has not only lost its name, it has also been separated from the plastic, both organisationally and physically, in the production process.[69] However they - the bumper and the bumper beam - are closely connected in the final car.

The separation of the plastic and the aluminium is connected to the bumpers' move inwards "into" the car and a new facility layout at Torslanda related to the introduction of the 850 series. In 1985, the RA board decided to invest in new plastic cap production facilities in Gent and Torslanda, close to Volvo's assembly plants. The idea of Just In Time had increased in Western automotive production and both Volvo and RA realised the potential benefits of a small geographical distance between production of plastic caps and the final assembly line. As the caps were supposed to be painted in colours defined by production, the need for storage would decrease when the caps were finished close to the final assembly site. A warehouse was therefore

[67] Interviews with Paal Brekke, Grete Valheim and Erik Bågarud

[68] Interview with Grete Valheim

[69] When I started my interviews in HAST, they all talked about their bumper production. Thus, my first trip to Volvo brought me to the Bumper Division as I thought that was the place I would find more information about the bumper beam. However, as the bumper and the bumper beam became separate physical entities they had also created an organisational divide. The Bumper Division was only involved in the foam and plastic and had stronger connections to the Design Division, while the bumper beam had moved to the Body Division and had stronger connections to the more structural components of the car.

leased outside Torslanda to store readily assembled bumpers with plastic caps.[70]

Ever since plastic cap production had started at Raufoss, this had run in parallel with the production of aluminium beams and there was no need for coordination other than checking that the plastic cap and the aluminium beam fitted together.

In 1997, Hydro decided to invest in a new bumper plant with injection moulding, painting and assembly just outside Volvo's Torslanda plant. The plant for producing plastic caps had an investment cost of NOK 300 million and was ready for production in 1998. Hydro did not intend to stay in the plastic cap business and was happy to form a joint venture with Gränges in 1999. The press release from Hydro reads as follows:

> "Gränges and Hydro are forming a new company, Autoplastics, where Gränges will own 60% and Hydro the last 40%…[the] agreement includes a unconditioned sales option and Gränges an unconditioned buying option. The requirements for release are mainly based on profits…[through] the merger we are realising a part of Hydro's long term strategy of concentrating the automotive operations within development and production of aluminium components and systems, among them bumpers in aluminium." (Anonymous 1999a)

The following year, Sapa acquired both Gränges and Autoplastics. Hydro's annual report from 2001 states:

> "EBITDA for Automotive Structures demonstrated a marked improvement in 2000 compared with the previous year. The improvement was primarily due to the gain from the sale of Hydro's 40 percent interest in Autoplastics AB in the second half of 2000." (Norsk Hydro 2002)

Thus, in hindsight, it looks like Hydro's involvement at Raufoss was, from the start, aimed at splitting the plastic and the aluminium businesses. Although the investments they made were higher for plastics operation than for aluminium operations, this was probably designed to ensure that they realised a good price for the plastics operations when sold.

[70] Interview with Per Harald Sørlien

Small changes – big problems: the bumper beam becomes hollow

The bumper beam for the Volvo 740 introduced in 1987 is the first with a hollow profile, as shown in Figure 3-10. With a hollow profile, movements and damages in small crashes are minimised. RA also produced the foam and the plastic cap covering the profile.

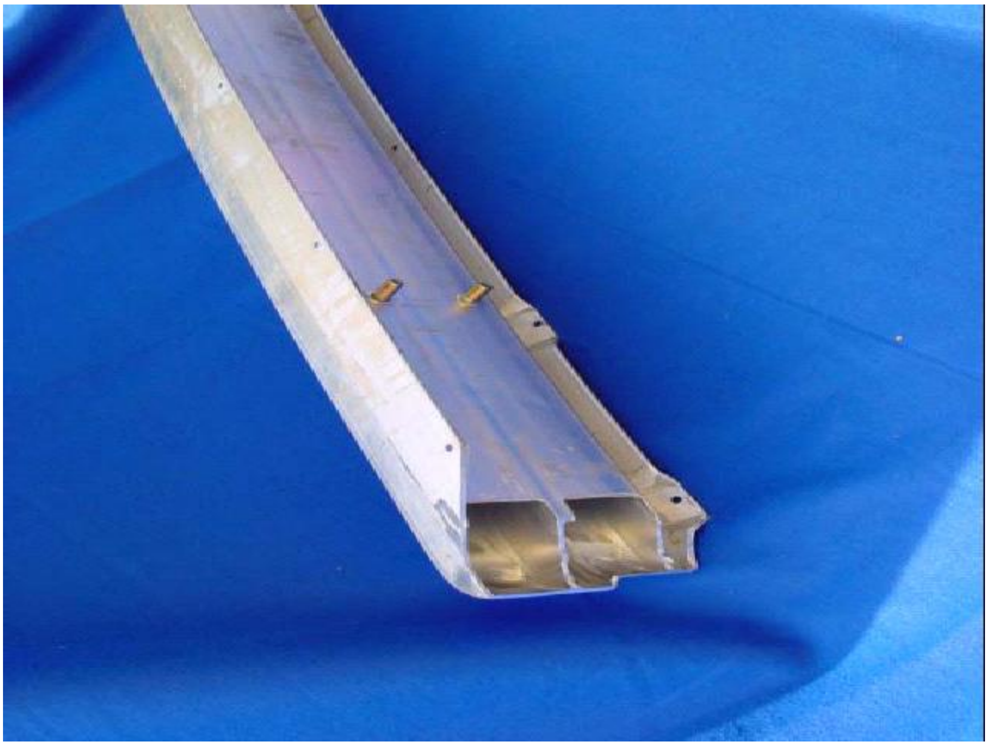

Figure 3-10 The first hollow bumper beam made for the Volvo 740 (image from Bjørn-Anders Hilland)

The hollow bumper beams could be made with reduced wall thicknesses, but retained better crash characteristics. As such, the solution had increased performance with less weight. Technically, however, it is much more difficult to produce a bumper beam with a hollow section than in one solid piece. The developments during the late 1980s were mostly related to production and the biggest change in the early 1990s was the creation of one common beam for the US market and other markets.

One common bumper beam for Europe and the USA came as a consequence of the bumper beam's move inwards towards the car body. When the bumper beam was fastened directly to the body, it was no longer possible to ship complete bumper assemblies with the metal beam, foam and plastic cap to be assembled in the USA. Bodies are sent from Torslanda with the bumper beam already attached. However, the thickness of the foam is different for the European and US markets. As a consequence, the bumper beams in Europe immediately became a little heavier to accommodate the US regulations, but re-reading the regulations also made it possible to make lighter beams for the US market. The regulation states that the car should be drivable after a collision, but what "drivable" means in practice requires a fair amount of individual judgement.

The conversion from solid profiles to hollow profiles does not sound like a big step. Of course, it is impressive that open sections can be made and that the aluminium can be welded as the metal is squeezed through the die tool. The challenge was, however, connected to the survival of the tools. The wear on the tools meant it was hard to earn money. During the initial attempts at making hollow profiles, the tooling costs exceeded the margins for the project. Tools were damaged after only a few billets and the relatively high tooling costs lead to financial losses. As a result there was concentrated activity during the 1990s to improve the operation. Cooperation was initiated with a Japanese producer of bumper beams, which led to improvements in productivity of several hundred percent, but this was still not enough. However, with a rearrangement of the tool set-up coupled with increased knowledge about optimal extrusion speed and temperature, the problems were solved. As an example of the improved efficiency, when the production unit in France was converted from the old to the new tool set-up, the lifetime of the tools rose from 50-60 billets to more than 1000 billets. This obviously led to a considerable improvement in the financial results.[71]

Assembly Technology

Volvo's assembly factory in Torslanda outside Gothenburg really consists of three separate factories: a body factory, a paint shop and a final assembly factory. During the first twenty years or so of the cooperation between RA and Volvo, there was no need for much consideration about the assembly technology in relation to the bumpers. Although there is always a problem in mixing metals (for example when the aluminium bumper is fastened to a steel body), the assembly process in itself was not very demanding. Most of the assembly work was done manually and this decreased the need for standardisation. However, as the bumper started to consist of more and more parts during the 1980s, consideration had to be given to how to make assembly as easy and efficient as possible. RA invested in a just-in-time warehouse outside Gothenburg in 1990. At first, complete bumper systems were sent from Raufoss, but after a while plastic covers, foam and bumper

[71] Interview with Sigurd Rystad

beams were transported there and the bumper system was assembled before being transported to the Volvo factory.[72]

During production of the Volvo 850 in the early 1990s, the factory was reorganised. The bumper and the bumper beam were separated, with the bumper beam moving from the final assembly line to the body factory. Thus, instead of being attached to the almost finished car at the end of the line, it left the body factory to go to the paint shop fastened directly to the body. This was part of the reorganisation of the production set-up at Torslanda. According to the Head of Strategy in the Bumper Division, it was absolutely necessary to cut development and production costs.

> "Until the 850, we had almost built a new factory for each project. Now we cannot afford that anymore."[73]

As a consequence, the factory has been rearranged to accommodate more standardised components. The final assembly still requires much manual work, but robots have taken over the body factory. About 500 robots are in place at the factory and two of these are assigned to the job of fastening the bumper beam to the car body. In recent years, the placement of the fastening holes in the bumper beam has been standardised so that the same robot with a similar program can be used for every car model, as shown in Figure 3-11.

[72] Interview with Per Harald Sørlien
[73] Interview with Head of Strategy, Volvo Bumper Division

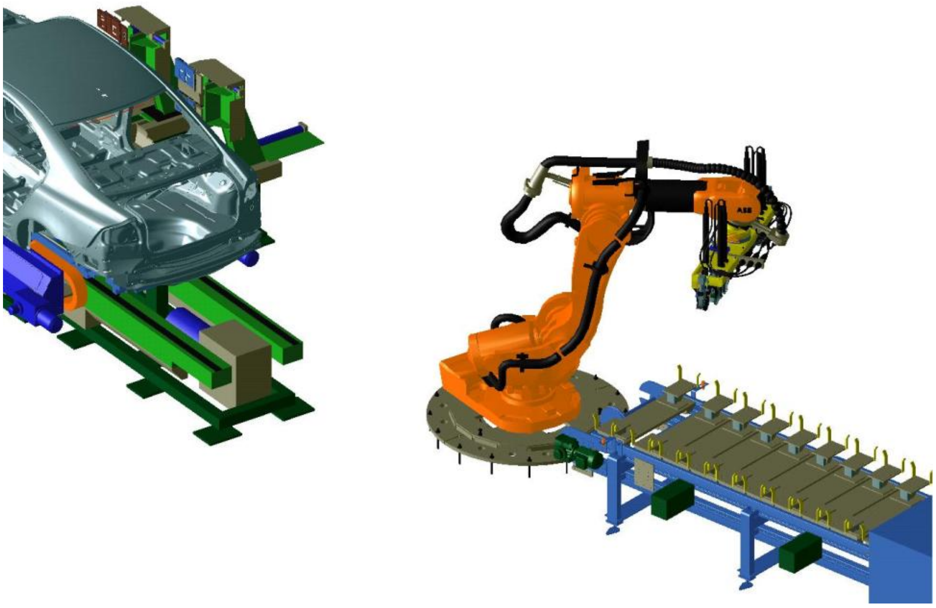

Figure 3-11 Robot for fastening bumper beams to the body (Image from Martin Weiman)

The robot is programmed to screw six screws in the exact same position for all models and the cycle time for the whole operation is 49 seconds per bumper beam, which includes checking that the bumper beam is correctly fastened.[74]

Better products

Figure 3-12 is an illustration of details on one of the newer bumper beams. Compared to the previous bumper/bumper beam images, the level of sophistication has increased dramatically. "For a long time, we used complicated machinery and tools to produce pretty simple products," as one of the development engineers said.[75] Although the level of sophistication in the bumper beam has increased, the production and set-up times have decreased. The bumper beams' movement inwards into the car has led to many more interfaces than when the bumpers were mounted on the outside. Now, factors such as air control to the engine and electricity for the lamps have to be considered in the design of the bumper beam.

[74] Interview with Martin Weiman
[75] Interview with development engineer in Hydro Automotive

The detailed design of the bumper beam includes elements that are made for transporting the car body with the bumper beam on the assembly line, for fastening the bumper beam to the body, for fastening the bumper to the bumper beam and for accommodating components with an interface to the bumper region, such as headlights.

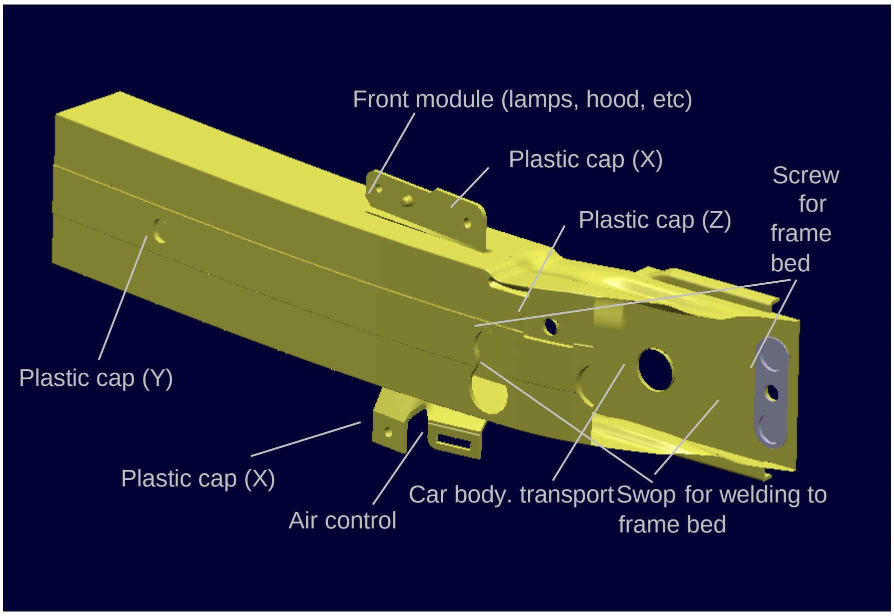

Figure 3-12 Details on the S 80 bumper beam (before facelift, image from Tobias Svantesson Kåvik)

Sources for the changes in the product include new regulations relating to bumpers, new design requirements and new test organisations doing crash tests on new vehicles. In the earlier discussion of the changes between 1970 and 1985, the US regulations for bumpers from 1972 and their update from 1982 were discussed. During the end of the 1980s and the following period, further work has been carried out to create new international regulations and standardise both the requirements and the set-up of crash tests. Unlike in the USA, European legislative bodies have been more interested in how bumpers can be made so that pedestrians are not injured if hit at low speeds. The combination of the two requirements - protecting the vehicle at high speeds and ensuring pedestrians do not sustain injuries at low speeds - is contradictory. The solution to meet both the requirements lies in the foam between the plastic cap and the metal beam. The metal beam itself does not contribute to pedestrian safety and "could just as well have been made of concrete."[76]

Test organisations such as the US New Car Assessment Program (NCAP) and Euro NCAP are set up to provide customers with information about the safety of new cars. They perform a multitude of different crash tests and publish rankings in newsletters and on websites. These organisations have both contributed to a standardisation of test methods and an increased focus on safety in car companies.[77]

There are few examples of components that can be used for more than one car model. Although different cars are often built on a similar platform, there are almost always small differences in design that means components must be changed.[78] In the newest Volvo projects, they have succeeded in making one common bumper beam for three car models, S80, V70 and XC70. The beam is shown in Figure 3-13. Compared to the bumper beam for the S80 before the facelift, there has been a dramatic decrease in weight. The original bumper beam weighed 5.37 kg, while the new bumper beam only weighs 3.74 kg. In one project they have managed to create a bumper beam for three different models with less weight than the original bumper beams. Thus, Economy* is created both in terms of economy of scale - as costs per unit decrease when more units are produced - and also because less material input is needed. When the major contribution of the aluminium price to the cost of the bumper beam is taken into account, this has a significant impact.

[76] Interview with Tobias Svantesson Kåvik
[77] As passive safety is traditionally one of Volvo's competitive advantages, the increased focus may actually be to their disadvantage. Although customers are more aware and better informed about the safety features of a car, it also means that all car companies feel the urge to fulfil the requirements, making every car more similar in terms of safety features.
[78] A project in GM showed that even small items such as screws are non-standardised. Interview with Grete Valheim

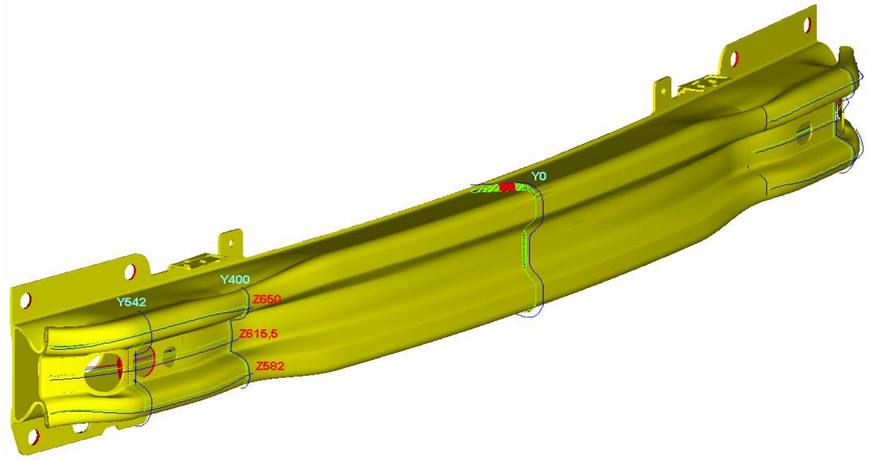

Figure 3-13 The new bumper beam for the S 80, V 70 and XC 70 (Image from Bjørn-Anders Hilland)

Notice how the details are placed at the ends of the bumper beam; this makes it possible to manufacture the beam without manual operations or the use of the CNC machine. We can see the three holes on the right side of the bumper beam that are used to fasten the bumper beam to the body. The large centred hole at the end of the beam is used for transporting the body. The beam is made in one piece, which is one of the primary reasons why an aluminium beam can compete with a steel beam despite the major differences in the price of the raw material.

An image of the fronts of the three car models is given in Figure 3-14 in relation to platform strategies.

Tools and technologies for efficiency: platforms, HAPS and the use of computers

From the mid-1990s, Volvo and HAST both started a systematic evaluation of their working practices to increase production efficiency. That is not to say that efficiency improvements were unheard of in the time up to 1995, but the systematic use of administrative and operational tools was not as evident in the past. Most of the tools and technologies described here started out as managerial concepts, but they do have real implications for how production is organised, what the products look like and how the relationship between the companies develops.

When the 850 model was introduced in 1991, it had been subject to almost ten years of development. These years were probably well spent, at least if judged by the changes in production that happened during the lifetime of the model. Development costs had started to rise so high that Volvo realised they could not rearrange the factory for every new model they produced.[79] As a result, at the time the 850 was ready for a facelift, Volvo introduced a pilot project connected to a platform strategy.

Platforms at Volvo

The "Painted Body" project was aimed at making production more efficient. It involved a reorganisation of the factory, but equally importantly it meant a reorganisation of the development and production areas, both in terms of their organisational structures as well as in new layouts for the office environment. Engineers and operators were placed together in cross-functional teams, new IT tools were introduced and the aim was to perform simultaneous engineering.[80] Between 1995 and 1998, Volvo worked on the introduction of the P2 platform. The first car built on the platform was the S80 in 1998 (von Corswant 2003). Later followed the V70, XC70, S60 and XC90, which may contribute to explain why Volvo managed to have the same bumper beam on three models (S80 after facelift, V70 and XC70) as explained earlier in the section on "Better products". Indeed, looking at the appearances of the cars as displayed in Figure 3-14, one can see that they are clearly similar.

[79] Interview with Stefan Johanson-Tingström
[80] Interview with Mats Bengtsson

Figure 3-14 The fronts of the three models (from top): V70, S80 and XC70 (images from Volvo cars).

The use of a platform strategy means that cars become more similar. The basic shapes cannot differ too much if the same components are to be used in more than one model.[81] However, the development and use of platforms is not only about using components for more than one model. The changes that have been introduced in Volvo have been as much connected to the processes of development and production as to the physical objects to which these processes relate. The platform concept "encompasses a total offering with vehicles that are built with the same modular structure using common systems and components and manufactured by using common flexible processes in cooperation with a group of long-term partners/suppliers and using common working methods."[82]

[81] Still, the number of models has increased. It is almost paradoxical how more and more models are introduced, while the models themselves are getting more and more similar.
[82] Interview with Mats Bengtsson

In parallel and in connection with platform development, there has also been a shift in the view of suppliers within Volvo. Although suppliers had some development responsibility in 1985, they have been much more involved in recent years. This has also led to a large reduction in the number of direct suppliers to Volvo. Since the rationalisation program started in 1995, the number of 1st tier suppliers has decreased from just above 375 to a little less than 100. At the same time, the number of models offered has increased from five to fifteen and the numbers of cars sold has risen from 350,000 to 600,000.[83]

HAPS

At the start of the new millennium, HAST introduced an improvement program called the Hydro Automotive Production Systems (HAPS). The program was an adjustment of what is known as Toyota Production Systems, often referred to as a Japanese production philosophy. The content of HAPS is a vision of how production should be undertaken in the future, with a staircase showing how the company could get there, as shown in Figure 3-15.

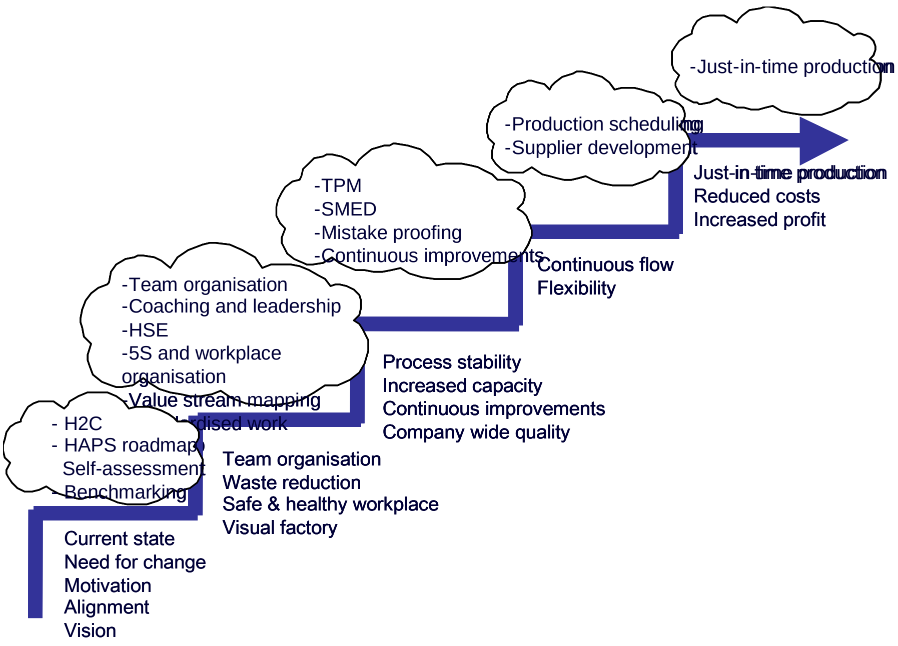

Figure 3-15 The HAPS ladder (image from Tom Wasenden).

[83] Interview with Mats Bengtsson

At every step, both the workers and the management have clear and simple tools and techniques to use to improve efficiency, reduce waste and thus increase earnings. The tools include unambiguous key performance indicators (KPIs) and a whiteboard with easy-to-read numbers and graphs. Every shift reports on issues such as the maintenance tasks they have performed, possible irregularities in machines, uptime and wreckage on the blackboard. If production has been running in accordance with the KPIs, the numbers are written with a green marker; if not, a red marker is used. This makes any deviations easy to spot. The whiteboard is shown in Figure 3-16.

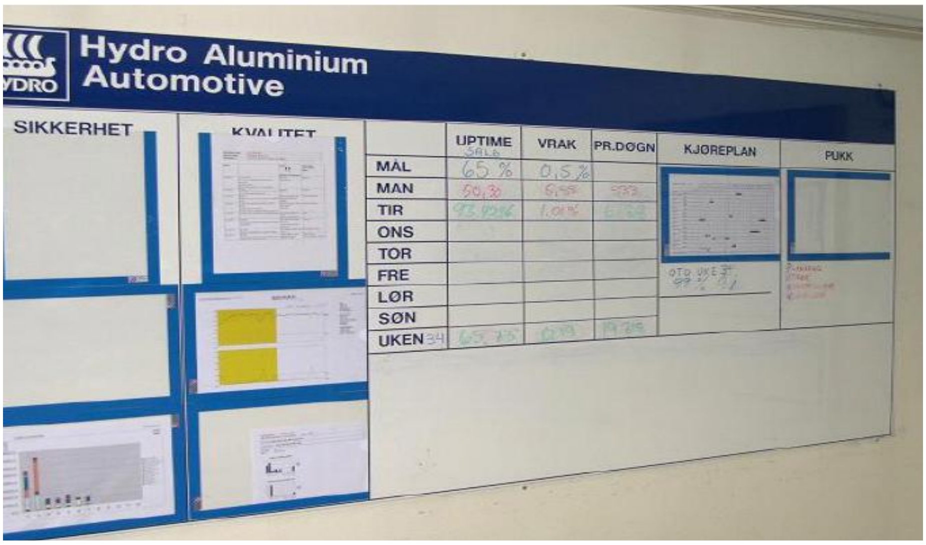

Figure 3-16 Whiteboard for production parameters (image from Tom Wasenden).

It is not only the organisation of whiteboards that is better arranged. One of the tools employed is called 5S and is about the organisation of the workplace, where the five S's stands for (with the Norwegian words in parentheses): sort (sortere), systematise (systematisere), shine (skinne), see to (se til) and standardise (standardisere). The different shifts are certified according to whether or not they live up to the standards of operational maintenance.[84]

Although the introduction of the system is driven by a desire to accumulate reduced costs relative to revenues (as depicted at the top right position in the staircase diagram in Figure 3-15), there is recognition of the workers' needs and wants. The tools themselves may look a bit patronising – for example, the machine operators are asked to keep their "room" tidy and to report

[84] Interview with Morten Aass

everything they do. However, the goal is to create greater independence for the workers. It is explicitly stated that the workers' acceptance and feeling of ownership are key in achieving the durable effects of changes.[85] As a consequence, HAPS includes team organisation across hierarchical levels in the company. Team meetings are held every morning for approx. 10-15 minutes to discuss production status and consequential problems. All the workers have attended a course on teamwork and the appointed leader of each team is given extensive training. One of the goals is to attain an atmosphere where mistakes can be shared, with the recognition that covering mistakes up may have devastating consequences (at best financial; at worst related to injury and even death).[86]

Thus, HAPS is not only a set of tools and techniques, but also reflects a shift in the philosophy underpinning the production of bumper beams at Raufoss. It has had real consequences with regard to variables such as uptime, conversion time from one product to another, consumption of oil, work-related injuries, precision of deliveries, lead time and complaints from customers. This has again led to improved financial results and also, of course, positively affected the relationships with HAST's customers, including Volvo.[87] For example, in the 1980s and 1990s, Volvo reported concerns with the relatively large number of errors in the deliveries from Raufoss. Such complaints have decreased in later years as delivery precision has increased.

Computers

One of the greatest differences between 1985 and 2006 is the way both development and production is carried out. In 1985, all the drawings in the development phase were made on paper, but by 2006, all the processes within the companies were heavily influenced by the use of computer tools. The transition to computer tools has made both the drawing process itself and the handling of drawings easier. A drawing on a millimetre sheet may create difficulties for the parties when tolerances are low. Now the drawing program in the computer, CATIA, gives exact coordinates that can be fed into the computers running the extrusion press and the forming line. Before even reaching production, the product is heavily tested in LS-Dyna, a simulation programme developed by the US army to simulate missile hits. The programme allows the construction engineers to specify material characteristics and the shape of the product. A range of alternative product shapes and compositions can be tested without having to make a number of

[85] Interview with Tom Wasenden
[86] Interview with Tom Wasenden
[87] HAST was awarded a prize from Toyota in 2003 in relation to their quality work.

prototypes. After simulation has been run by Hydro and accepted by Volvo, but before production starts, computers are used in bidding on the LME to obtain the most favourable prices for aluminium. Computers are also instrumental in accounting, in storing information related to the other tools and in transferring regulations and evaluation schemes.[88]

One of the effects of the introduction of computer tools is that the supplier needs to adapt to the manufacturer's choice of tools. If the tools used in development by the different parties are unable to communicate, the project is stranded.

Although the computers make information transfer and storage easier, this does not come without costs. The almost exponential increase in costs for development is related to the more intensive use of computers.

What business is the business of bumper beams?

The heading for this section may seem like a question that is only of academic interest, a question of how to categorise entities with few real-life implications. In reality, it is the opposite. The question is key in numerous decision-making situations in which one tries to understand how to create Economy*. At the end of the 1990s, Hydro Aluminium was in charge of a supply chain of bumpers consisting of a cast house, an extrusion plant, a forming line and facilities for the production and painting of plastic caps. What was the focus? Were the main products aluminium alloy billets or extruded profiles or bumper beams or plastic caps? Were the business units in the automotive industry? Or in the aluminium industry? Or in the plastics industry?

To answer the last question first, the response is clearly "No!" The plastic cap was obviously not included in Hydro's ideas about how to run production at Raufoss. This also rules out the plastic caps as the main product. The other questions are, however, more difficult to answer. In the late 1990s, it was unclear whether the management in Hydro Aluminium saw the unit at Raufoss as a bumper-producing or an aluminium-producing operation.

> "For a while [the management in Hydro Aluminium] wanted us to report the amount of aluminium sold. We told them that our goal is to sell as little aluminium as possible – per unit."[89]

[88] Interviews with Tobias Svantesson Kåvik and Peter Holmén.
[89] Interview with Bjørn-Anders Hilland

For an aluminium company it is normal to report the amount of aluminium going through the system, as it is one of the parameters that can be used to calculate which company is the largest aluminium company in the world. For HAST, as exemplified by the citation, the high costs of aluminium had made it paramount to keep the amounts as small as possible to be able to compete with bumper beams in other materials.

This may be a minor example, but there is no doubt that there is tension between the unit at Raufoss and the larger Hydro Aluminium organisation. When Hydro announced its intention to divest itself of the automotive operations on 13 November 2006, it was accompanied with the following statement by Hydro's CEO, Eivind Reiten:

> "When Hydro decides to sell a business it's because we believe the operations and employees will have a better home with a company that sees greater potential for value creation in that business than we do." (Anonymous 2006)

He added that Hydro would focus on the area of primary aluminium production and production of a variety of extruded products, including building systems. The decision reveals a conflict that has been present at Raufoss since bumpers first were produced there. The profit margins to be gained in the automotive industry are much less than in, for example, construction. The tension has been present since Hydro acquired ÅSV. A tension that has led to Raufoss never really being part of Hydro and talk remaining about "us and them" on both sides. Raufoss *is* different. It is the only production site for 7000-series alloys and it has the largest extrusion press in the entire Hydro Aluminium system, which has a total of around 100 presses.

HAST grew extremely fast during the late 1990s and the beginning of the new millennium, increasing its production from about two million bumper beams in 1995 to more than six million bumper beams in 2003. One of the consequences being that the contribution of Volvo products to HAST's turnover has been going down in relative but not absolute terms. Nevertheless, the focus on Volvo has decreased as other projects have stolen the attention. The deliberate decision not to continue as a system supplier in the new supplier organisation at Volvo has also played a part. From being a supplier of bumper systems with a high requirement for coordination with Volvo, they became a second tier supplier with a lower level of responsibility for development and sourcing.

At Hydro Aluminium, the central decision was made not to seek more bids during 2002. HAST complained that it just showed that the parent organisation did not understand the automotive industry and its focus on long-term contracts. A car model is usually produced for about six years with additional production for fifteen years for after-market sales. Every contract thus means incomes for a long period of time.

During the 1980s and onwards, it has been a trend for international aluminium companies to consolidate and integrate vertically. The major companies are expanding, mainly by acquiring the smaller ones and leaving only a few logos to be displayed on the map of the aluminium industry. Spreading of risk, securing supply and material competence have been some of the arguments behind the trend. These have probably been some of the reasons for Hydro's involvement at Raufoss (and later in VAW). The automotive industry may have seemed tempting in the mid 1990s when the arrow for car manufacturers was again pointing in the right direction after a drop in sales (and therefore earnings) at the beginning of the 1990s – particularly as the prices for primary aluminium were low. Afterwards the image has blurred: the automotive industry did not grow as fast, whilst the price of primary aluminium grew even faster.[90]

In every annual report from Hydro since Raufoss entered the publication in 1995, there have been complaints about the financial position of the automotive part of the aluminium business. Every report has stated a need for rationalisation and better handling of costs. Unfortunately for Raufoss, or at least so it seemed at the end of 2006 (and given that they really wanted Hydro as the owner), the financial struggles with automotive operations made Hydro finally announce their desire to get rid of the whole automotive division.[91]

3.3.4 Summary: important elements connected to bumper production between 1985 and 2006

The time that passed from 1985 to 2006 included several changes in all three layers that form the bumpers' industrial network (actors, resources and activities). The plastic cap took over the role as the bumper and the aluminium beam was pushed inwards towards the engine. No longer was the producer of the aluminium beam the same as the producer of the plastic cap. Furthermore, the beam became hollow, which required totally new forming

[90] It is rather ironic that high aluminium prices are good for Hydro Aluminium in total, while at the same time bad for HAST

[91] As this part of the thesis is written in 2007, I can now reveal that the automotive operations at Raufoss were not sold. As the oil and gas operations in Hydro merged with Statoil, Hydro is no focusing solely on aluminium production and aluminium products.

tools. The billets began to be produced at Raufoss with aluminium from the London Metal Exchange (in practice: Russia) instead of billets produced at Sunndalsøra, with aluminium from the same place. In 2006, the parties in the relationships were no longer RA and Volvo, after Hydro had acquired RA in the mid-1990s. It can also be contested whether Volvo was sitting at the other end of the table after Ford's acquisition of Volvo in 1999.

Actors that were added between 1985 and 2006 include Ford, Hydro, Plastal, LME and vehicle test organisations. ÅSV and the two divisions belonging to automotive production within RA disappeared. The production at Raufoss was instead split between three different units - HAMP (Hydro Aluminium Metal Production), HAP (Hydro Aluminium Profiles) and HAST (Hydro Automotive Structures) - under the common umbrella HARA (Hydro Automotive Raufoss). The bumper was shifted from the Bumper Division to the Body Division within Volvo.

There were also changes in the resource layer as plastic forming tools disappeared while many new resources were introduced. A new cast house, new extrusion presses and new forming lines were acquired at Raufoss and new assembly technology introduced at Torslanda. Standards related to impacts on pedestrians and new car designs created less packing space for bumpers, leading to hollow bumpers with more complex geometrical shapes. Hollow bumper beams required new extrusion tools. Supplier evaluation schemes, supplier policies and management tools such as Volvo's platform strategy and Hydro's HAPS were introduced to implement changes in production as well as requirements from new actors. Different types of computer software have been instrumental in steering changes in both production and organisation.

The actors and the resources has been involved in several changes of activities, such as simulations, drawing, new forms of cooperating, new ways of assembling, better integration of casting, extruding and forming, changes in logistics activities and new ways of sourcing raw materials.

Together, all these changes have altered the content of the Economy*, but it is not only changes in the three layers that affect this content. Keeping elements stable may have consequences that are just as significant.

3.4 Elements that have stayed the same – investing in stability

The text so far has focused on actors, resources and activities that have changed and important elements that have contributed to these changes.

There are, however, a few characteristics that are holding this case together, that make it into being about one issue although activities, resources and actors constantly change (as we have seen). These characteristics are *aluminium beams in 7000-series alloys from extruded profiles delivered from Raufoss to Torslanda*. Keeping these constant has not meant that they have been neglected or not debated. On the contrary, an enormous amount of work is often needed to keep things stable. In the following section, the different elements of stability will be scrutinised to show the economic consequences of and economic reasons for this investment in the maintenance of stability.

Extrusion presses and profiles

The first bumper contract between Volvo and RA was more or less a coincidence, a series of more or less deliberate moves that suddenly pulled in the same direction, e.g. RA's decision to start production of aluminium profiles, Volvo's decision to use aluminium profiles for their bumpers and Volvo's decision to have more than one supplier to spread the risk.

This basis for the continued relationship in relation to bumpers may have created a lock-in effect, but the results of the US safety regulations and the oil crisis in 1973 should not be underrated as arguments for why Volvo made the decision to continue to use aluminium bumpers.

The continued use of bumpers would not, however, have made sense if the development of the processes connected to the aluminium bumpers and the output, that is the bumpers themselves, did not match the development of the cars at Volvo. Looking at the products, for instance in Figure 3-5 and Figure 3-13, reveals that a lot has happened in relation to the shape of and accessories on the bumper beams, but examination of the production process does not reveal the same degree of development. That said, one of the earliest extrusion presses from the late 1960s is used in the production of more and more advanced products. There are two possible reasons for this:

One is given by an extrusion expert at HAST, who says:

> "Presses are like aeroplanes, they look the same on the outside, but the details keep changing so they never get too old."[92]

Although the extrusion press looks similar in a photograph taken in 1970 and one taken in 2006, the insides have been completely renewed and the computer programs used to run the presses have been regularly updated.

[92] Interview with Sigurd Rystad

Thus, even if the production process looks similar at the outside, the elements inside have changed. This also hints at a relationship between the manufacturer of the extrusion press and the manufacturer of the bumper beam. Every summer, a team from the press manufacturing company comes to Raufoss to perform maintenance and to do test runs.[93]

The other reason why the press can look the same and yet still meet new requirements is given by one of the development engineers:

> "It is only in the last few years that we have started to produce products that are as refined as the production process."[94]

This can also be an argument for a disconnection between the complexity of the tool and of the product. He states that the bumper beams of 2006 could also have been made at an earlier point in time. However, there was probably no pressure for complex geometrical shapes when the bumpers were mounted on the outside of the car, with less requirements to fit inside a tight packing volume.

The 7000-series alloys

RA's development of 7000-series alloys together with ÅSV was one of the main reasons for RA establishing itself as a bumper producer. The 7108-series alloy (the one that was denoted 2054 by ÅSV and RA) fulfilled the demand that was created by the introduction of FMVSS and the almost simultaneous oil crisis. It combined strength with low weight to such a degree that RA suddenly became a preferred supplier for several European carmakers exporting to the USA.

In more recent years, it has become clear that the strength of the alloy is not the most important feature, as the requirements from legislation are not as tough as imagined by the automotive industry during the 1970s and 1980s. As a result, the advantages of the 7000-series alloy have turned into disadvantages. The stronger alloy used in bumpers meant that the wall thickness could be thinner and thus the bumper could be lighter. So, although there are potential weights savings by employing a 7000-series alloy, the absolute weight of the product is going down and the relative advantage of 7000-series alloys compared to 6000-series alloys is shrinking. Taking into consideration the fact that the 6000-series alloys are much more common and easier to recycle, the price of the billets could be lowered by converting to the 6000-series alloys. 6000-series alloys also have an

[93] Interview with Sigurd Rystad
[94] Interview with Tobias Svantesson Kåvik

advantage because they allow faster extrusion and forming, plus shorter hardening periods.[95]

Nevertheless, HAST has decided to stick to 7000-series alloys, although they make bumpers with 6000-series alloys if asked by their customers. Part of the reason for this "stubbornness" is connected with the argument they have employed for almost 40 years – that the 7000-series alloys actually perform better. Another (and possibly more important), part of the reason is connected to the production process. All developments and adjustments over the years have been made according to 7000-series alloys, which means that the process is optimised for such materials. A switch to 6000-series alloys would therefore not give immediate production advantages, as the whole process would have to be re-optimised for the new alloys.[96]

Raufoss

The deal that was negotiated between Volvo and RA had a small ironic touch to it. Originally, when the ammunition producer RA was established in 1896, its location was picked for its inaccessibility for the Swedes. At the end of the 19th century, Norway and Sweden were on the edge of war and the Norwegians were afraid that Sweden would use force to destroy Norway's dream of independence. To obtain ammunition for a possible war, the Norwegian government decided to start production at Raufoss, as its location inland "behind" Norway's largest lake, Mjøsa, made it hard to access for the Swedes. This would, perhaps, have been an advantage in any war with the Swedes, but in a business relationship it is clearly a disadvantage. Although the transport infrastructure was better developed in 2006 than it was in 1896, logistics have been a continual issue in the relationship between RA/Hydro and Volvo.

The interlude with plastic cap production at Raufoss shows that the placement of a factory is not decided forever. Plastics operations were moved from Raufoss and closer to production localities in Sweden and Belgium to obtain better conditions for just-in-time production. So one is bound to ask why the production of the aluminium bumper beams has stayed in place.

Raufoss is not located close to the aluminium production site, so access to raw materials should not be the issue. The aluminium is even (again with a touch of irony) shipped from Gothenburg to Raufoss. One could argue that this makes transport more efficient, as trucks can also be loaded on return

[95] Interview with Torgeir Welo
[96] Interview with Torgeir Welo

trips to Raufoss,[97] but the logical conclusion of such an argument would be to place production of bumper beams in Gothenburg to stay close both to the supply of aluminium and to the customer of the bumper beams.

The machinery already present at Raufoss may be one of the actual reasons for not moving production. Cast houses, extrusion presses and forming lines are capital-intensive, heavy machines that are not easily moved. However, new pieces of all of these items of equipment were purchased during the 1990s and they could have been placed in Gothenburg or Belgium instead.

Then there is the access to human resources. The long tradition of mechanical workshops at Raufoss has been used as an argument for why industry is still present and growing. Although the mechanical workshop does not develop or produce extrusion tools, it does produce forming tools of a high standard. Coupling the industrial equipment with the human knowledge has probably created a lock-in effect (i.e. the necessary stability) to ensure continued production at Raufoss.

Torslanda

When Torslanda was established in 1964, it was probably an obvious choice. Except for those countries without car production, the automotive industry was mainly a national affair. Export sales were treated as a bonus in addition to national sales, but the automotive industry has become rather more global since then. So the same question applies for Torslanda as for Raufoss: why is there still car production at Torslanda?

As for Raufoss, Torslanda is situated far from both markets and natural resources. Again, all the heavy machinery may be one factor but probably of greater importance are all the connections that have been established with Torslanda. Without reverting to cultural arguments, the long tradition of machine industry in Sweden has been vital to enforce the connections in Torslanda. Since the beginning, Volvo has relied heavily on suppliers in order to produce cars. The ability to manage the assembly of parts from the outside is therefore one of the most significant assets for the Torslanda site.

[97] Aluminium billets are transported from Gothenburg to Raufoss on trucks that have transported plastic bumpers produced by Plastal at Raufoss from Raufoss to Gothenburg. Interview with Roy Jakobsen

3.4.1 Summary: important factors in keeping elements in place from 1970 to 2006

The most important resources and activities in this section were those given in the headings, namely extrusion presses, aluminium profiles and connected activities, as well as 7000-series alloys and the activities needed to develop, produce and process them into bumpers at Raufoss and mount them on cars at Torslanda. In addition, there are all those actors, resources and activities that made these resources and activities stable over time. These latter are, however, not required to be stable themselves. Rather there is a need to change elements adjacent to those that are kept stable, such as the inside of the extrusion presses, the knowledge of the different alloys and the competence of the workforce.

3.5 Summary and timeline

The chapter has shown the content of and the changes in the Economy* over a period of almost 40 years. Actors, resources and activities involved in bumper transactions between a bumper producer at Raufoss and a car manufacturer at Torslanda have been presented. New theories on what constitutes Economy* have constantly been produced, based both on the available resources and activities, and the more or less conscious altering of adjacent resources and activities. The word 'theories' does not here refer to formal science based theories, but rather to scripts or processes that are used to undertake the transformations from natural resources scattered over many places into a specific bumper beam in a specific place. Such new theories have been more or less explicit, with the changes that resulted from the introduction of the plastic cap as an example of the latter and the introduction of HAPS or the platform strategy in Volvo as examples of the former. These elements (and others) have altered the content of the Economy* through a change in the composition of elements. New theories have confronted the ones already in existence and the outcome (not in monetary terms, but in the resulting processes) has both been affected by and affected the relationship itself, adjacent relationships and the activities, resources and actors these encompass.

More theoretical words like consolidation and specialisation could of course be used to make sense of the described changes in the Economy*. However, these words are only elements that take part in the story as far as they make their way into discussions and decisions in the industrial network. There have been instances where such words – or rather the concepts they allude to – have clearly dictated decisions made by the companies. No attempt has been made, however, to establish links to theoretical models that perhaps have contributed to the actors' understanding of activities and resources.

Furthermore, it is important to remember that this chapter is not mainly directed towards explaining why changes in the Economy* have occurred (although the description implies explanations). Rather, the aim has been to display the elements of the Economy* and how these have appeared and/or changed and/or disappeared during the time span covered, so that these elements can be compared with elements from the Environment*.

3.5.1 Important actors, resources and activities

To keep track of the elements that have been part of the Economy* between 1970 and 2006, they can be sorted according to the ARA model.

Actors

In 1970 there were few actors involved in the Economy*. RA supplied bumpers to Volvo. The aluminium input came from ÅSV and extrusion was performed in the joint company Alprofil. Rubber strips were supplied by Mjøndalen Gummivarefabrikk.

In 1985, after the introduction of the plastic cap, the metal part of the bumper was no longer visible. This change was facilitated by a reorganisation at Raufoss into two divisions for bumper production: RA Automotive and RA Autoplastics. Plastic for the plastic caps was supplied by Statoil and competence in plastic forming acquired by hiring two employees from Skriver Industrier. The metal part had also changed and was heavier and stronger due to a bumper standard introduced in the US in 1972 by NHTSA. The bumper standard increased the demand by European car manufacturers exporting to the US for strong bumpers that were lighter than steel bumpers. RA being one of the few producers of such, this led to an expansion of RA's customer base. It also led to RA being the sole supplier of bumpers to Volvo models manufactured in Sweden, because Gränges could not present the same development capabilities as RA in cooperation with ÅSV.

In the late 1970s, Volvo's CEO Pehr Gyllenhammar tried to negotiate a deal with the Norwegian Government (with Jens Chr. Hauge as their negotiator) to get Volvo licenses to drill for oil in Norwegian waters, thus also becoming an oil company. Volvo would have had to invest large sums in Norway and set up a car factory. Although the negotiations failed because Swedish shareholders opposed the deal, it led to at least one research project involving RA.

In 2006, neither RA nor ÅSV existed anymore. ÅSV had merged with Norsk Hydro in 1986 and the company took the latter actor's name. Norsk Hydro acquired the automotive operations in RA in two steps in 1993 and 1995. The bumper customer, Volvo, had been acquired by Ford. Between 1990 and 1993 Volvo cooperated with Renault and this almost ended with a merger.[98] In fact, bumpers were no longer what were transacted between the companies, as the plastic caps had "stolen" that name. The shift in product specification also led to an emphasis on two different divisions in Volvo, namely the Bumper Division and the Body Division. Plastic operations were sold out by Hydro - first by forming a joint company with Gränges and thereafter with the transfer of the whole of the company to Sapa (later known as Plastal). At Raufoss, the organisation was split into three sub-units: Hydro Aluminium Metal Products (HAMP), Hydro Aluminium Profiler (HAP) and Hydro Automotive Structures (HAST). These units were to be coordinated by Hydro Automotive Raufoss (HARA), although they were also supposed to have their own individual business targets and accounts. Aluminium was no longer supplied internally, but instead purchased from the London Metal Exchange (LME), which in practice meant Russian aluminium producers.

In addition to all these actors, there were plenty more present in the network from 1970 to 2006. These include transporters, suppliers of extrusion presses, suppliers of extrusion tools, suppliers of robots for bumper forming, suppliers of robots for assembly, vehicle test organisations, other sub-units within the larger organisations and numerous decision-makers and workers that have been invisible in the text, but that clearly must have been responsible for putting resources into use, combining them and placing value on them, as well as conducting and changing activities.

Resources

Many of the important resources have already been encountered in the summary of the actors, such as bumpers, bumper beams, plastic caps, extrusion presses, extrusion tools, forming tools, robots and factories for the painting of plastic caps and assembly.
From the start, aluminium billets were supplied by ÅSV to RA. In the early 1970s, a re-smelting plant was set up at Raufoss that mostly handled internal recycling. In the 1990s, a new cast house was built, with aluminium ingots and other metals being purchased at Raufoss to make their own aluminium billets.

Throughout the entire time period, the billets have been extruded at Raufoss, although there was a major shift in the set-up of extrusion tools with the introduction of hollow bumpers at the end of the 1980s. The hollow bumpers

[98] Again Swedish shareholders opposed the deal and it led to Pehr Gyllenhammar resigning from his position.

allowed for thinner wall thickness and more complex geometries, both decreasing the weight of the product and making it suitable for less packing volume (the space available for the beam between the plastic cap and the engine of the car).

The introduction of a standard for bumpers in the USA in 1972, the Federal Motor Vehicle Safety Standard (FMVSS) 215, paved the way for the safety bumper. The inclusion of the plastic cap in the late 1970s required facilities for production and painting of plastic caps.
All these technical resources have been facilitated by organisational resources such as the organisation of organisational units and management tools such as Volvo's production platform and the Hydro Automotive Production System (HAPS).

Computer tools have been instrumental in the latter stages of the time period in the development of both technical and organisational resources, including specialised software for bumper drawings and simulations, software for running extrusion presses and forming / assembly robots, purchasing software, databases for supplier evaluations and more. The input and output of the different software units have been important resources in themselves, e.g. drawings, requirements for bumpers from standards and supplier evaluation schemes.

Throughout the entire period, the finances of the companies and the competence they have contained have been important factors, as well as the location of production and storage of products.

Activities

Having presented both actors and resources, the important activities involved in the Economy* from 1970 to 2006 are almost given. The production of bumpers/bumper beams has always required the production of aluminium, aluminium alloys and aluminium billets, which have provided the input for extruding aluminium profiles. These profiles have needed forming to attain the right shape. In the early years, the bumpers were anodised before a rubber strip was attached and they were transported to Torslanda and mounted on cars. Both the anodising step and the rubber strip disappeared with the introduction of the plastic cap, but other activities were undertaken instead, such as plastic forming and plastic painting.

Even before production starts, other activities need to be performed, ranging from negotiating, developing facilities and searching for suppliers to designing cars, drawing bumpers and purchasing materials.

3.5.2 Timeline of the Economy*

The actors, resources and activities presented in this chapter can be organised according to the time of their introduction or alteration as shown in Figure 3-17.

	Activities	Resources	Actors
1970[99]	Bumper making	Cast house, extrusion press, roll forming equipment, manual assembly	ÅSV, RA, Volvo
1971			
1972		Legal requirements, safety bumpers	NHTSA
1973		Oil crisis	
1974		Cast house	Several new customers
1975			
1976			
1977			
1978			
1979		Plastic forming technology	Statoil
1980	Plastic forming		
1981	Painting	Paint factory	
1982	Roll forming ends		
1983			
1984			
1985			
1986			Hydro acquires ÅSV, ALPROFIL is dissolved
1987		First hollow bumper beams	
1988			
1989			
1990			Volvo and Renault form strategic alliance
1991			
1992			
1993		Introduction of LS-Dyna at Raufoss	Volvo and Renault want to merge, but fail
1994	Bumper and bumper beam divide		Hydro acquires 40% ownership of RA
1995		New cast house, introduction of platform strategy	
1996	Casting increased		
1997			Hydro acquires rest of RA
1998	Plastics production is moved	Introduction of HAPS	
1999		New extrusion press Several new documents introduced	Ford acquires Volvo
2000			Hydro sells "plastics"
2001			
2002			
2003		New supplier policies from Ford	
2004			
2005			
2006			

Figure 3-17 Timeline of the Economy (the introduction or change of activities, resources or actors).*

[99] The elements (actors, resources and activities) displayed in 1970 were already in place and were not introduced or changed that specific year.

3.5.3 An adjusted image of the economy

The Economy* encountered in this chapter does not at all look like the stereotypical view of the economy presented in the introductory chapter. The cynical rationale we could have expected to meet has been absent.

Instead, from 1970 to 2006, we met actors who have struggled to make resources fit each other and external demands. They have really made an effort to create the best possible Economy*. This is not to say that the Economy* has been optimal at every point in time. Rather, the Economy* has been the end point that the companies are striving to reach, a position somewhere in the future where costs are lower and income is higher. At least three different industries have made their presence felt: the automotive industry, the aluminium industry and the plastics industry. In addition, reference has been made to the influence of the steel industry, the oil industry and the insurance industry. These have different modes of operation, different organisational methods for creating Economy*, both between each other and internally. The activities undertaken and the resources employed in development and production have shown significantly different characteristics, with consequences for the actors' attempts at organising them.

The actors have strived to come to grips with what resources to hold on to and what resources to let go. This is easy to understand, given that both the actual resources and the perceptions of them have changed constantly. The changes in the object of exchange, the bumper/bumper beam, have been massive. Its dimensions, its shape and its material composition are significantly different in 2006 compared to 1970. Changes in resources or in the structure of activities or the interdependencies between pairs of activities often created change in other activities. Anodising disappeared when the plastic cap was introduced, whilst at the same time activities related to the production of plastic caps had to be put in place; this introduction eventually led to the creation of a warehouse closer to Torslanda, resulting in a change to the logistical structure and thus the activities needed to transport the product to Volvo. Plastic activities were again separated from the bumper beam when Volvo rearranged assembly and Hydro decided to focus on its core activities.

Such changes have not been confined to tangible resources only. In an advertisement from 1974, Volvo wrote:

> "Buying a Volvo is an investment. It's been built carefully and slowly to give you years of trouble-free driving, few repairs and little servicing…Most cars are built fast and they fall apart fast. A Volvo is

> built very, very slowly. It takes nine hours just to get through final assembly." [100]

Compared to the systematic attention to cut down on the time spent in production during the later decades, the advertisement seems odd. However, it shows a shift in the conception of time from being a sign of quality to a sign of waste. Many resources (including the resource of "time") are spent on reducing the time in production. We have encountered methods such as HAPS and the Volvo platform, as well as schemes for evaluating and qualifying suppliers. The latter is an example of a resource demanding time to ensure that the production process itself runs smoothly.

The actors have pursued growth opportunities, but also invested in security. This applies to both the major organisations and the individuals. For the organisations, relationships have played an instrumental role in this respect. Close relationships such as the ones between RA and ÅSV and between RA and Volvo have provided stability for development and for testing new technical and organisational solutions. At the same time, this closeness led to increased harmonisation between the parties and less flexibility to alter resources and activities. When RA expanded its customer base in the mid-1970s, it was granted access to other technologies and other ways of producing. This access has inspired innovations and reorganisations at Raufoss. Thus, both close relationships and multiple relationships are platforms for technical development and gaining economy. However, both close relationships and multiple relationships are consuming resources. History shows that the relationship between RA and Volvo was at its closest when RA had few other close relationships. When RA increased the number of customers and thus relationships, its relationship with Volvo became weaker.

Changes in the actor layer have mostly taken place as a consequence of an actor having financial trouble, an actor wanting to gain more economy or a combination of both. Hydro and ÅSV merging, Volvo and Renault attempting to merge, Hydro's acquisition of RA, Hydro's sale of plastic activities and Ford's acquisition of Volvo are all examples on this. They tell a story of the need to achieve economy now in order to be able to create greater economy in the future. The trust and commitment between the parties are increased with the knowledge that the opposite party has the finances to bear a loss.

We have only dealt with those activities where the companies producing a specific car are directly involved, yet many activities that take place

[100] Volvo, 1974, ”The Volvo Fact Kit: ’74 Model Year Edition”

elsewhere are just as important for the car, such as politicians issuing laws and regulations for products and processes and other car-makers inventing new designs.

Economy may not be any less political than only a few decades ago, but it seems as if business companies have broken their bonds to politicians to a large degree. Politicians were less visible in the later stages of the history and it leaves the impression that Economists* (here used as a term describing people that perform the Economy*) were left more on their own – at least in the actor dimension. However, politics (represented as rules and regulations) did seem to be ever-present. The framework for the bumper beam became more rigid in terms of specifying its characteristics.

Even if the Economy* was different from the stereotypical view of the economy, there were few, if any, elements that resembled the stereotypical view of the environment.[101] It remains to be seen whether the Economy* has any resemblance or connections to the Environment* - at least until the content and the development of the Environment* from 1970 to 2006 have been revealed in the next chapter.

[101] Except, maybe, for the emotions involved when a company has been acquired by another.

4. Scientific production of bumpers and bumper beams: creating the Environment*

I want to investigate the aluminium bumper as a research report with a focus on the environment to answer two questions, namely 1) *What is the environmental status of the bumpers?* and 2) *How has such an environmental status come into being?* The answers to these questions will provide a picture of what the Environment* is and how it has changed over the last few decades. This will provide an overview of the Environment* comparable to that of the Economy* as scrutinised in the previous chapter. The purpose is thus to describe the Environment* and how it is produced over the same time period as that for the Economy*, i.e. from 1970 to 2006.

Just as production of the physical bumper beam requires materials to be produced and transported all over the world so they can be refined into the product, the production of the bumper beam as a research report requires knowledge production from diverse fields to be transported, amalgamated and refined. Most of the travel to unpack the relations between the bumper beam and the environment takes place in journals. Articles are linked through references to establish connections between different topics and to confirm viewpoints so that truths can be established. We shall see how physical properties are translated into graphs, figures and words. However, not much of this journey will be spent actually investigating the equipment used for translations, i.e. the technologies used to discover and measure environmental impacts, other than through the descriptions of the equipment offered by the articles.

Bumpers and bumper beams are quite specialised equipment with a low level of direct interest from researchers outside the automotive industry, although there are aspects about the bumpers that are interesting to environmental scientists. However, it is important to bear in mind that bumper beams do not constitute a science in themselves - rather, different sciences can be used to advance knowledge of them.

Naturally, scientific contributions on bumpers do not stretch far back in time, as, arguably, the first car was only built by Benz in 1885 (Stein 1961). This is at least portrayed as the first vehicle built with the intention of including a combustion engine from the start. The first bumpers did not appear until after the turn of the century, the turn from the 19^{th} to the 20^{th} century that is, and the first article about bumpers I have managed to locate across was published in 1924 (Reyburn 1924). Although the article refers to other work on bumpers, it contains no references. The main message from the article is a plea to car manufacturers to make the attachment of bumpers easier; remember this was written before bumpers became standard equipment on cars:

> "A bumper is a bar attached transversely in front of or behind a car body to prevent contact between an obstruction and the car body or to cushion the shock of collision between vehicles […] In recent years few other accessories have been so unsatisfactorily attached to automobiles as have bumpers. However, provision for their application has been neglected by car manufacturers. One or two additional holes would greatly simplify the labor of attaching them and would also reduce the cost to the car-owner. Bumpers at the same elevation on colliding cars are twice as effective as those of different elevations. Although specifications cover this height, many bumpers fail to conform to them. An appreciation of the protective power of bumpers and closer cooperation between car and bumper manufacturers would result in a reduction of the growing list of automobile casualties" (p. 379)

The silence around bumpers continued for decades, broken only by occasional articles, until around 1970, when the enforcement of regulations seems to have stimulated more widespread publication on the issue. Although Reyburn's (1924) plea for better attachment of bumpers to cars seems to have been heard since the customers no longer had to attach them themselves, the issue of bumpers at different elevations was still a major concern and the subject of occasional research articles (e.g. Happer et al 2003; Nielsen et al 1997).

That said, most articles on bumpers in general, and aluminium bumpers in particular, are of a different nature. They focus on technical issues with the materials used or the performance of bumpers (e.g. Brusethaug & Langsrud 2000; Dons et al 1999; Fjeldly et al 2001; e.g. Hansen et al 2004; Skjerpe et al 1987; Syvertsen 2006), where concerns such as "isotropic elasticity, an anisotropic yield criterion, associated flow rule, combined non-linear isotropic and kinematic strain hardening, and strain-rate hardening" (Reyes et al 2006) are discussed.

Three different scientific representations of aluminium bumpers are given in Figure 4-1 below.

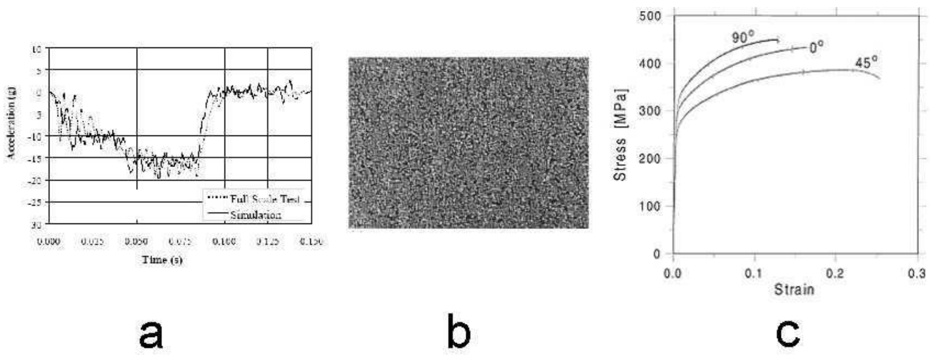

Figure 4-1 Three scientific representations of bumpers.

The image shows a) the crash impact of an aluminium bumper as acceleration vs. time (Eskandarian et al 1997), b) the surface of an aluminium bumper through an electron microscope (Miller et al 2000) and c) a stress vs. strain curve for an extruded aluminium bumper profile (Clausen et al 2000). Although these representations do not immediately show signs of having any connection to the environment, they do show the same mechanism of chains of translations necessary to capture materials on paper as will be shown for the Environment*. In other words, they show how physical properties of an object are displayed by creating connections between the object itself and already established scientific categories. This makes it possible to quantify the characteristics of the bumpers through the aid of measuring equipment. The images thus become true features of the bumpers.

The word 'environment' in the context of natural surroundings is connected to the work done by Jakob Johann von Uexküll, an Estonian biologist who invented the term 'umwelt' when studying the life of ticks (Von Uexküll 1934). However, the history of environmental studies, by which I mean studies related to the deterioration of natural surroundings, goes far back in history with a book by James Hutton (1788), reckoned to be one of the classic early texts on this subject. Environmental studies are not just based on environmental studies, meaning that several sciences are needed in order to look at environmental problems. The contribution to understanding a specific environmental problem may have been created for a wholly different purpose but later enrolled into an actor-network stabilising the idea of that environmental problem. Such connections between different scientific findings will be explored in this chapter. The environment as it is perceived is dependent on what perception categories it may contain, i.e. what we take to be nature is partly determined by how it is described by others, and to an increasing degree these others are scientists.

The remainder of the chapter concerns research where these two areas - bumper research and environmental research - are brought together. However, to understand the Environment*, emphasis will be placed on research into environmental issues. Trails will be followed to understand the connection between the Environment* as depicted in articles from science related to bumpers and in sciences related to the environment.

4.1 A reference point for the Environment*

I could have tried to construct a research report myself that considered the connections between an aluminium bumper beam and the environment in 2006. Fortunately, an attempt to capture such connections had already been published in 2000 when Christian Thiel from Adam Opel (the car manufacturer Opel) and Georg B. Jenssen from Hydro Raufoss Automotive presented a paper called "Comparative Life Cycle Assessment of Aluminium and Steel Bumper Carriers" at the Total Life Cycle Conference and Exposition in Detroit, Michigan on 27 April (Thiel & Jenssen 2000). This article, hereafter referred to as the Thiel article, will form the basis for an investigation of what the Environment* is with regard to the bumpers and/or bumper beams and how the Environment* has been created, transformed and stabilised throughout the years. To complete such an investigation, the Thiel article is viewed as an actor-network in itself: a textual presentation of connections between established truths about the environment, materials for bumper production, emissions, weight savings, policy-makers etc. However, to avoid anticipating the course of events, the search will start with a summary of what the article states, some keywords (i.e. actors) and the references (also actors) to guide the search for how the network has been constructed and stabilised. The stability, and hence the truth, of the actor-network will depend on the strength of the different elements and how they are made to fit together.

4.1.1 First round: environmental issues from the Thiel article and its references

The aim of the Thiel article is to analyse the environmental aspects of two alternative materials for bumper carriers.[102] Steel and aluminium were chosen and "the presentation of the results focuses on air emissions as CO_2, CO, NO_x, and SO_2 for the LCI and on the impact categories global warming

[102] Bumper carriers are the same as bumper beams and bumper reinforcement bars.

potential, eutrophication potential and acidification potential for the LCIA" (p.1).

There is no justification for why the three impact categories were chosen or what they refer to in terms of environmental harm, nor are we told whether there are other impact categories that have been excluded from the study. The word 'potential' for each of the categories hints that these are not observable environmental impacts, but rather impacts that may occur. Perhaps the air emissions chosen by the authors are especially coupled to driving and/or aluminium production and/or steel production?
The first section of the article continues:

> "The achieved weight reduction by the use of light weight material and the replacement of primary metal by secondary metal resulting from recycling of ELV scraps were identified as the two parameters which have the biggest impact on the LCA results. They have been studied in two sensitivity analysis" (p.1).

Light weighting and recycling are emphasised as important features for the environmental status of the bumper carriers. The abbreviation ELV is not explained and leaves an uninformed reader still uninformed. A few pages later we are indeed given information on what can be saved from a reduction in weight:

> "According to the EUCAR-LCA report [a weight reduction] of 10% leads to a fuel consumption and consequently CO2-emission reduction of 6%. The other air emissions like NOx, CO and HC undergo transformation through the catalytic converter and can not be allocated to the part's weight."

The carbon dioxide emissions are thus directly related to the weight of the material of the bumper. We do not know how the weight affects emissions of SO_2, but NO_x and CO are now tied to the production of the bumper rather than the use of the car.

As the name ("Comparative Life Cycle Assessment of Aluminium and Steel Bumper Carriers) implies, the article is based on a life cycle assessment (LCA). The authors state that LCA is an "accurate and widely used approach to achieve an analysis of the entire life cycle of vehicles and components in regard of raw materials use and emissions" (p. 1). However, LCA is not defined in much greater detail, although we are told: "the LCA-study has been conducted according to the requirements of the ISO 14040 and ISO 14041" (p.1). It would appear that someone has thus already defined how an LCA study should be conducted and probably also what an LCA study is.

This should be borne in mind as we start the search for what LCA is and how it relates to the Environment*.

In the Thiel article, a broad section is used to explain the boundaries of the two production systems (i.e. those of aluminium and steel). The different recycle scenarios are also presented, as well as the data sources used for the steel part and the aluminium part. The results are then presented - first with an overview of the emissions of the different chemical components in the different life cycle stages and then with a presentation of the break-even point for CO_2 emissions between the steel and the aluminium part. Finally we are given the answer to the question about sulphur dioxide:

> "Other atmospheric emissions [than CO2] such as carbon monoxide, nitrogen oxides and sulphur oxides are regulated during the use phase by the activity of the catalytic converter and can not be directly linked to the influence of the parts' weight. Therefore, a break even point for those gases can not be calculated" (page 4).

It is thus only CO_2 that varies with the use phase. The article continues with more results and the bumper carriers are translated into graphs showing their contributions to the various potentials (i.e. impact categories) in the separate parts of the life cycle and for the total life cycle. The figures below show the results as they are pictured in the article. First is the global warming potential (GWP) from part production, as shown in Figure 4-2.

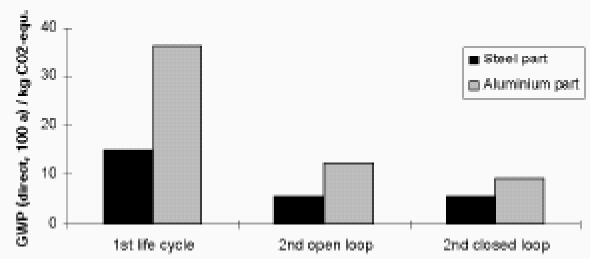

Figure 7. Part production: global warming potential

Figure 4-2 Results for the global warming potential in the part production stage of the life cycle (Figure 7. from the Thiel-article. Reprinted with permission from SAE Paper # 2000-01-1495 © 2000 SAE International)

Production of the aluminium bumper carrier causes a higher global warming potential than its steel equivalent, whatever the degree of recycling. The bars on the left represent production without recycled material and the authors stress that the GWP is higher than the CO_2 emissions because aluminium production causes the release of CF_4 and C_2F_6 during the electrolysis step. This proves that the article does indeed cover other emissions. These four gases from the life cycle inventory are complemented with others as they reach the life cycle impact assessment. There is no explanation for the global warming potential other than a reference to a methodology developed by the IPCC, an abbreviation we will need to check further.

The results section continues with a graph depicting the acidification potential (AP) from the production life cycle stage, as shown in Figure 4-3.

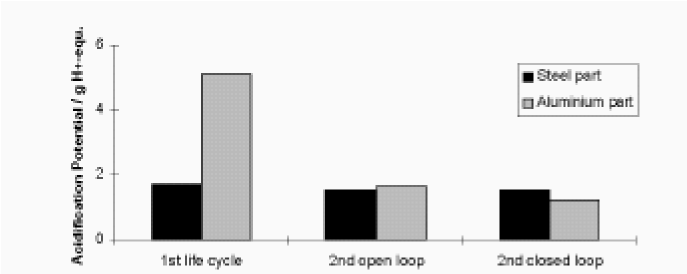

Figure 8. Part production: acidification potential

Figure 4-3 Results for the acidification potential in the part production stage of the life cycle. (Figure 8 from the Thiel-article. Reprinted with permission from SAE Paper # 2000-01-1495 © 2000 SAE International)

> "The acidification potential is 3 times higher for the aluminium part production compared to the steel part production in the first life cycle, 10% higher in the second life cycle open loop and 18% lower in the closed loop scenario" (p. 5).

We are given to understand that the acidification potential is closely related to the degree of recycling of aluminium, which is not surprising considering that only production releases are accounted for. However, we do not know which emissions, i.e. which gases, are leading to the acidification potential or what the acidification potential is really a measure of.

The article then presents eutrophication potentials (EP) for the different scenarios, as shown in Figure 4-4.[103]

[103] If you are wondering what 'eutrophication potential' means, this will hopefully become clear when we continue the search to understand what it is and how it has come into being

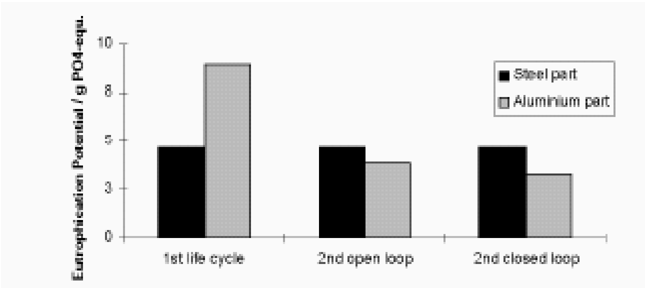

Figure 9. Part production: eutrophication potential

Figure 4-4 Results for the eutrophication potential in the part production stage of the life cycle (Reprinted with permission from SAE Paper # 2000-01-1495 © 2000 SAE International).

> "The eutrophication potential is 1.9 times higher for the aluminium compared to the steel part production in the first life cycle, 16% lower in the second life cycle open loop and 30% lower in the closed loop scenario" (p. 5).

The conclusion is the same as for the acidification potential but, as before, the gases are not mentioned. What the eutrophication potential actually measures is not revealed.

After the results for the production phase, the article continues with its "real" interest, namely the impact potentials for the entire life cycle of the bumper carriers. Figure 4-5 shows the results for the entire life cycle within the scenario where none of the materials are recycled.

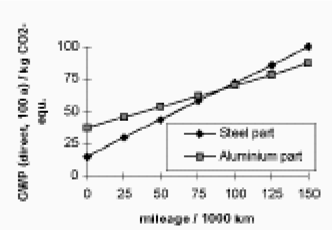

Figure 10. Entire life cycle: global warming potential

Figure 4-5 Results of GWP for aluminium and steel for the entire life cycle but without recycling (Figure 10 from the Thiel-article. Reprinted with permission from SAE Paper # 2000-01-1495 © 2000 SAE International)

Without recycling, "the break even point for the GWP for the aluminium in comparison to the steel part is at about 93000 km" (p. 5). It therefore takes quite a significant number of miles to reach the stage where the GWP is the same for aluminium and steel. However, the conclusion is altered quickly when recycling is taking into account, as shown in Figure 4-6.

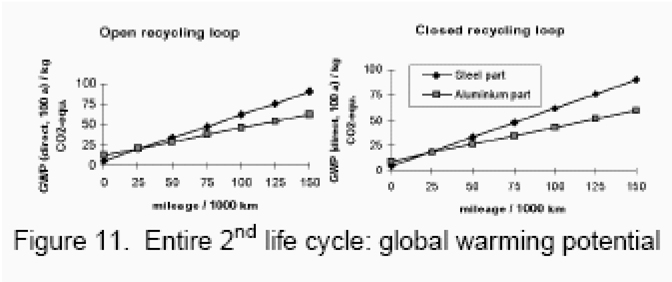

Figure 4-6 Results of GWP for aluminium and steel for the entire life cycle but with recycling - 2 different scenarios (Figure 11 from the Thiel-article. Reprinted with permission from SAE Paper # 2000-01-1495 © 2000 SAE International)

> "The break even point for the GWP for the aluminium in comparison to the steel part is at about 29000 km in the second life cycle open loop and 17000 km in the closed loop scenario" (p. 5).

Here the larger GWP from the production of the aluminium part is soon exceeded by the larger GWP during the use phase of the steel part. Thus, the conclusion of the article is that the aluminium part is better than the steel part with regard to GWP. However, no conclusions are offered in relation to AP and EP, both because they are too dependent on the level of recycling and because the catalytic converter makes it hard to be certain if the reduction of CO, SO_2 and NO_x emissions is caused by a reduction in weight.

Several concepts mentioned in the summary will be subjected to further scrutiny, including:

- Global warming potential, eutrophication potential and acidification potential
- LCA
- Life cycle phases, i.e. production, use and disposal
- Lightweight materials in cars
- Recycling and ELV
- Aluminium production

The Thiel article has provided some information on these issues, but we still know little about what the environmental impacts are and how the other issues are connected to them. Let us therefore take a look at the references to see if they can aid us in understanding the role of these actors in constructing the Environment*. Figure 4-7 displays the references as given in the article.

REFERENCES

1. ISO (1997): International Standard 14040 – Environmental Management - Life Cycle Assessment –Principles and Framework. International Organisation for Standardisation, Brussels
2. ISO (1998): International Standard 14041 – Environmental Management - Life Cycle Assessment –Goal and Scope Definition and Life Cycle Inventory Analysis. International Organisation for Standardisation, Brussels
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4. Laboratorium für Energiesysteme ETH Zürich (1996): Ökoinventare von Energiesystemen, Zürich
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6. European Aluminium Association (1996): Ecological Profile Report for the European Aluminium Industry, Brussels
7. EUCAR (1998): EUCAR Project R3 - Life Cycle Analysis, Data and Methodologies, Phase 2 - Final Report, Brussels
8. Intergovernmental Panel on Climate Change (1994): Radiative Forcing of Climate Change. The 1994 Report of the Scientific Assessment Working Group of IPCC, London
9. Centre of Environmental Science (1992): Environmental life cycle assessment of products. Guide and Backgrounds, Leiden

Figure 4-7 The references in the article (The references from the Thiel-article. Reprinted with permission from SAE Paper # 2000-01-1495 © 2000 SAE International)

Numbers 1 and 2 are ISO standards specifying the LCA methodology (ISO 1997; 1998). Numbers 3 to 6 are material databases (for steel, energy, aluminium and plastics, respectively). Number 7 is a report by EUCAR and gives an argument for the decrease in fuel consumption and, hence, emissions with a decrease in weight. Number 8 is an explanation of the calculation for global warming potential by IPCC and number 9 is an explanation of the calculations of acidification potential and eutrophication potential from a report written by the Centre for Environmental Science at the University of Leiden. The last two references should be directly linked to the Environment*, as they explain the three impact categories. Global warming potential, acidification potential and eutrophication potential will therefore be examined first.

Global Warming Potential

The reference for global warming potential in the Thiel article brings us to an IPCC report published in 1994, called "Climate Change 1994: Radiative Forcing of Climate Change." Chapter Five of this report is dedicated to so-called "Trace Gas Radiative Forcing Indices", which, with careful reading, corresponds to Global Warming Potential (GWP). However, we are not directly introduced to the GWP concept. First, the authors have to express what the radiative forcing indices are based on.

> "Radiative forcing indices have been developed as a relative measure of the potential globally averaged warming effect on the surface-troposphere system arising from emission of a set amount (e.g. 1 kilogram) of a variety of trace gases. These gases can exert a radiative forcing of the climate system both directly and indirectly. Direct forcing occurs when the emitted gas is itself a greenhouse gas. Indirect forcing occurs when chemical transformation of the original gas produces or destroys a gas or gases that themselves are greenhouse gases. The indices reflect the cumulative radiative forcing over some chosen time period of interest" (Houghton et al 1994, p. 209).

Although the language is likely to be strange for most readers, at least some understanding can be gained from the paragraph. We can see that radiative forcing indices, which soon will be equal to GWP, are relative measures of the potentials different gases have to affect the global temperature in both direct and indirect ways. However, as the reading continues, it becomes clear that these are not just potentials that can be discovered out in nature.

> "*A relative radiative forcing index is not purely a geophysical quantity, such as is a change of temperature*. Rather, these indices are user-oriented constructs whose calculation involves not only an understanding of a few relevant Earth-system processes (e.g. radiation transfer and chemical removal), but also some policy-oriented choices (e.g. a selection of the time span of interest). Hence, such indices per se are not subject to observation and testing in the sense of many climate-system predictions, but are best judged by (i) their representativeness of the overall radiative forcing role of the specified trace gas and (ii) their overall usefulness to those who formulate and establish policies regarding the greenhouse gases…[*The focus*] *in the formulation of radiative forcing indices is on the effect of anthropogenic emissions of greenhouse gases*" (Ibid, p. 212, italics in original).

The radiative forcing indices are thus not only a translation of nature; they also include the political decision-maker, or at least a potential political decision-maker. They are therefore hybrids of physical, chemical and political processes as further elaborated below:

> "Common to all greenhouse gases are three major factors – two technical and one user-oriented – that determine the relative contribution of addition of 1 kilogram of a greenhouse gas to radiative forcing and hence are the primary input in the formulation, calculation, and use of relative radiative forcing indices…Factor 1: *the strength with which a given species absorbs long wave radiation and the spectral location of its absorbing wavelengths*…Factor 2: *The lifetime or response time of the given species in the atmosphere*…[and] Factor 3: *The time period over which the radiative effects of the species are to be considered*" (ibid, pp. 212-213).

The technical factors in the article are thus those directly related to processes in nature and the characteristics of gases, the atmosphere and solar rays. We now know that different gases vary when it comes to their ability to heat up the atmosphere - both because they absorb long wave radiation to a different degree and also because they have different lifetimes in the atmosphere. This is shown in Figure 4-8.

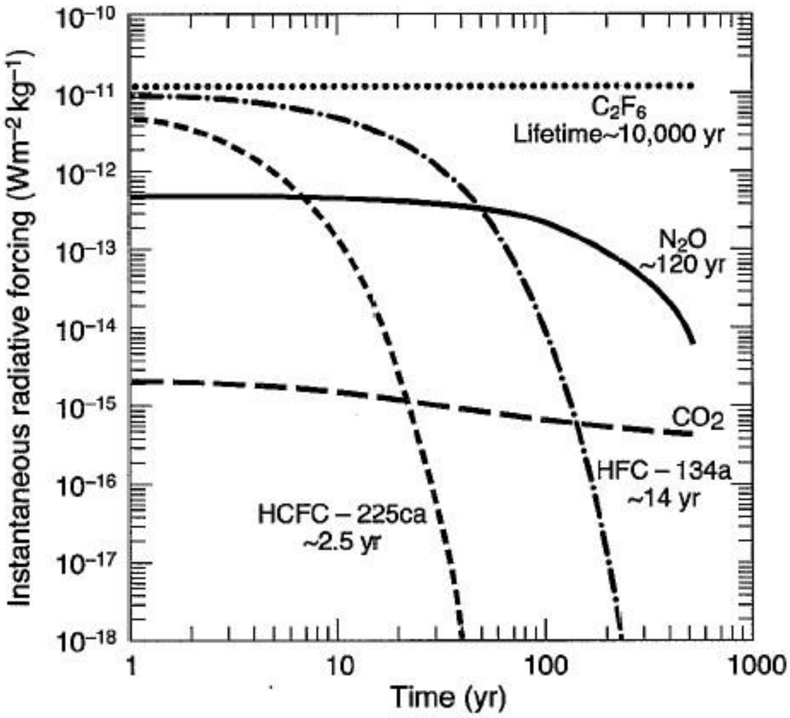

Figure 4-8 Strength of absorption and length of lifetime for several different greenhouse gases (Houghton et al 1994, p. 213)

It is worth noting the long lifetime of C_2F_6, which was one of the gases mentioned in the article as producing a higher GWP for aluminium part production. Furthermore, the graphical representation of the different chemicals almost produces a feeling of how they drop out of the atmosphere and down to earth after a given time.

The third factor, the time period to be considered, is not a feature of physical or chemical processes, but a feature of political processes, that is for what reason the radiative forcing indices are being used. An imaginary policy-maker is included in the text as three time-spans are displayed; 20 years, 50 years and 100 years. Finally, on page 215, we reach the Global Warming Potential:

> "[The relative] potential of a specified emission of a greenhouse gas to contribute to a change in future radiative forcing, i.e., its Global Warming Potential (GWP), has been expressed as the time-integrated

radiative forcing from the instantaneous release of 1 kg of a trace gas expressed relative to that of 1 kg of a reference gas (IPCC 1990):

$$GWP(x) = \frac{\int_0^{TH} a_x \bullet [x(t)]\, dt}{\int_0^{TH} a_r \bullet [x(t)]\, dt}$$

where TH is the time horizon over which the calculation is considered; a_x is the climate-related, radiative forcing due to a unit increase in atmospheric concentration of the gas in question; [x(t)] is the time-decaying abundance of a pulse of injected gas; and the corresponding quantities for the reference gas are in the denominator. The adjusted radiative forcings per kilogram, a, are derived from infrared radiative transfer models… [The] trace gas amounts, [x(t)] and [r(t)], remaining after time *t* are based upon the atmospheric lifetime or response time of the gas in question and the reference gas, respectively" (p. 215).

Simple as that!! Although there is an obvious misspelling in the equation, as an r is substituted with an x in the time-decaying abundance in the denominator. However, the point is rather to see how the atmosphere and the heat balance on the Earth are translated into a mathematical equation - how the ability to absorb energy and warm the globe fits in one line (or two if you consider the bar between the numerator and denominator to be a line space). However, the equation still lacks information about the reference gas - but this is provided soon after:

"The reference gas has been taken generally to be CO2, since this allows a comparison of the radiative forcing role of the emission of the gas in question to that of the dominant greenhouse gas that is emitted as a result of human activities, hence the broadest interest to policy considerations…[Unfortunately] from the perspective of its selection as the reference gas, the atmospheric response time of CO2 has the largest scientific uncertainty of the major greenhouse gases. As described in chapter 1, the uptake of CO2 is a complex process involving the biosphere, ocean, ocean-atmosphere exchange rates, deep ocean sediments, etc. furthermore, CO2 is also re-circulated among these reservoirs at an exchange rate that is poorly known at present, and it appears that the budget of CO2 is difficult to balance with current information. As a result, when CO2 is used as the reference, the numerical values of the GWPs of all greenhouse gases are likely to change, perhaps substantially, in the future simply because research will improve the understanding of the removal processes of CO2" (p. 215).

More of what the environment entails is introduced here. All of a sudden, the atmosphere is coupled to the biosphere, the ocean and deep ocean sediments

- and we get a link back to the article. We get a little understanding of why CO_2 is so important. Further exploration of this issue will have to wait until later, until other references can give us the scientific information.

Acidification potential

The article by Thiel and Jenssen (2000) gives no explanation for the acidification potential. They do not explain what it is, rather they refer to a report published by Heijungs et al in 1992. The chapter on acidification potential (AP) begins by stating:

> "Potential acid deposition onto the soil and in water is the end point of the classification for acidification. Potential acid deposition can be expressed as potential H+ equivalents. Potentially acidifying emissions of SOx, NOx and NHx can be aggregated on the basis of their potential to form H+. In the calculations of H+ equivalents it is assumed that one mol of SO2 will produce two mols H+, that one mol nitrogen oxide compounds (NOx) will produce one mol H+ and that one mol reduced nitrogen compound (NHx) will produce one mol H+ equivalent. Potential H+ equivalents provide an example of an exposure factor" (Heijungs et al. 1992, p. 75).

Immediately we are thrown into soil and water considerations. Some of the potentially acidifying emissions are to be found in the Thiel article, namely SO_2 and NO_x. We are now told that these can produce H+. However, the consequences of having this H+ in soil or water are not clear and may require additional reading:

> "As proposed by Vermeire *et al* (1992) an *acidification potential* (AP) can be developed by analogy with GWP, ODP and POCP. In this way the AP is defined as the ratio between the number of potential H+ equivalents (ν_i) per mass unit substance *i* (M_i) and the number of potential H+ equivalents (ν_{ref}) per mass unit of a reference substance (M_{ref}). Sulphur dioxide (SO2) is proposed as the reference substance. Expressed as a formula:
>
> $$AP_i = \frac{\nu_i / M_i}{\nu_{SO_2} / M_{SO_2}}$$
>
> " (p. 75)

Not much clearer… but we are at least given a formula relating the acidification potential to production of H+ and references are made to GWP, ODP and POCP, noting that we have already encountered the first. The fact that there are other abbreviations ending with a 'P' hints that there may be other impact categories and therefore other descriptions of environmental impacts, not covered by the Thiel article. But how does the formula relate to the environment?

> "The calculation of the *acidification potential* (AP) of a substance *i* is calculated on the basis of the number of H+ ions which can be produced per mole substance. This is given by the stoichiometric coefficient ν in the equation:
>
> $$X + \cdots \rightarrow \nu H^{+} + \cdots$$
>
> Where X is the acidifying substance. As environmental interventions are specified in kg emission rather than moles this has to be divided by the molecular weight M of the substance:
>
> $$\eta(mol \cdot kg^{-1}) = \frac{\nu}{M\,(kg \cdot mol^{-1})}$$
>
> The *acidification potential* of substance *i* (AP_i) is obtained by dividing η_i by η_{ref}.
>
> $$AP_i = \frac{\eta_i\,(mol \cdot kg^{-1})}{\eta_{SO_2}\,(mol \cdot kg^{-1})}$$
>
> " (Ibid. p. 100)

The text only specifies how to do the calculations; how the acidification potential is related to chemical equations consisting of chemical concepts such as stoichiometric coefficients, moles and molecular weights. Fortunately, the authors have already performed the calculation for a range of components, as shown in Figure 4-9.

TABLE 3.4. Calculation of the acidification potential of a range of acidifying substances.

compound	reaction equation	ν	M (kg·mol^{-1})	η (mol·kg^{-1})	AP
SO_2	$SO_2 + H_2O + O_3 \rightarrow 2H^+ + SO_4^{2-} + O_2$	2	64	1/32	1.00
NO	$NO + O_3 + \frac{1}{2}H_2O \rightarrow H^+ + NO_3^- + \frac{3}{4}O_2$	1	30	1/30	1.07
NO_2	$NO_2 + \frac{1}{2}H_2O + \frac{1}{4}O_2 \rightarrow H^+ + NO_3^-$	1	46	1/46	0.70
NO_x*	-	1	46	1/46	0.70
NH_3	$NH_3 + 2O_2 \rightarrow H^+ + NO_3^- + H_2O$	1	17	1/17	1.88
HCl	$HCl \rightarrow H^+ + Cl^-$	1	36.5	2/73	0.88
HF	$HF \rightarrow H^+ + F^-$	1	20	1/20	1.60

* For NO_x an average value of 2 was used for x.

Figure 4-9 Table showing acidification potentials for different substances (Heijungs et al 1992).

In this table, we are given both the numbers for the different variables that can be inserted into the equations to produce final values for the AP and the actual final values for the AP.

We have seen how different chemical compounds are translated into a single function - one of producing acid – but the impacts and detrimental consequences of acid deposition are not explained. For this category, we are not even given any connection to nature except for the chemical compounds. No species are mentioned and the words 'water' and 'soil' are the only link to nature.

Eutrophication potential

When opening the report by Heijungs et al (1992), I was puzzled that the word eutrophication was not included in the contents. With closer reading, however, I located a footnote in the chapter on nutrification that reads: "Here nutrification is used as synonymous with eutrophication. In this report this includes over-fertilisation of water as well as soil" (p. 75). Thus, the term eutrophication is explained. It is taken to be the same as nutrification and it affects water and soil. Now we just need to find out what nutrification is and this amplifies the hint that was given at the beginning of this chapter by Heijungs:

> "Nutrification is the addition of mineral nutrients to the soil or water which increase production (van Straalen & Verkleij 1991). This definition implies that nutrifying substances could always be a constraint on biomass production…Nitrogen (N) and Phosphorous (P) are the most nutrificating elements" (p. 75).

This makes it clear that nutrification is related to the production of biomass and that the two chemical compounds nitrogen and phosphorous are involved. It sounds like something farmers do to obtain a good crop. However, another footnote tells us that this is not the case: "The saturation of agricultural land with phosphorous due to excessive use of fertilizer in agriculture, which reduces the fertility of the soil and promotes nitrate leaching to the groundwater, does not fit into this definition of nutrification. Nitrate leaching could be classified under the problem type human toxicity" (p. 75). Further reading is perhaps required, in order to really understand what nutrification is about.[104]

> "The effects of nutrification must be distinguished between soil nutrification and nutrification in surface waters. In both media nutrification will result in generally undesirable shifts in the numbers of species in ecosystems and a reduction in the ecological diversity. The reduction in diversity is due to the fact that increased N and P levels make species which grow rapidly and at an early stage more competitive. Hence these species will displace those which grow slowly and later. This results in a reduction in diversity and the dominance of one or a few species which grow rapidly and early. In surface waters the shift in the range of species is generally shown by rapid algal growth. In some seasons when the algae die and at night when the algae consume rather than produce oxygen, this increased algal growth may lead to a lack of oxygen. This can have serious effects on the flora and fauna in the affected body of water" (p. 76)

The detrimental effect of nutrification is thus connected to diversity, to upholding an environment with rapid- and slow-growing species side by side. However, the only species introduced are algae and we can only guess that the effects are also felt by fish, seaweed and other flora/fauna living in waters.

> "A reference substance could be used to express nutrification…[In] this way a *nutrification potential* (NP) can be derived for all potentially nutrifying substances. Here the NP is defined as the ratio between the potential biomass in N equivalents per emitted quantity of substance *i* (M_i) and the potential biomass in N equivalents per emitted quantity of a reference substance (M_{ref}) such as PO_4^{3-} . Expressed as a formula:

[104] It should also be recognised that we are introduced to yet another category of environmental impacts, i.e. human toxicity.

$$NP_i = \frac{\nu_i / M_i}{\nu_{PO_4^{3-}} / M_{PO_4^{3-}}}$$

" (p. 76. Italics in orginal).

Nutrification is made calculable by referring to phosphate. However, this is not enough. We need to go one step further

> "The calculation of the *nutrification potential* (NP) of a substance *i* is based on the average composition of algae: $C_{106}H_{263}O_{110}N_{16}P$ (Eijsackers et al 1985), which is assumed to be representative of the average composition of biomass. For each nutrient X it is determined to what extent it contributes to the formation of biomass, assuming that the supply of other nutrifying substances is unlimited:
>
> $$X + \cdots \rightarrow \nu(C_{106}H_{263}O_{110}N_{16}P) + \cdots$$
>
> …The stoichiometric coefficient ν has to be divided by the molecular weight M of the substance concerned [as emissions are normally reported in kg, not moles]:
>
> $$\eta(mol \cdot kg^{-1}) = \frac{\nu}{M(kg \cdot mol^{-1})}$$
>
> The *nutrification potential* of substance *i* (NP_i) is obtained by dividing η_i by η_{ref}.
>
> $$NP_i = \frac{\eta_i(mol \cdot kg^{-1})}{\eta_{PO_4^{3-}}(mol \cdot kg^{-1})}$$
>
> The table shows the nutrification potential of various nutrifying substances.

TABLE 3.5. Calculation of the nutrification potential of various nutrifying substances.

compound	ν	M (kg·mol^{-1})	η (mol·kg^{-1})	NP
N	1/16	14	1/224	0.42
NO	1/16	30	1/480	0.20
NO_2	1/16	46	1/736	0.13
NO_x*	1/16	46	1/736	0.13
NO_3^-	1/16	62	1/992	0.10
NH_4^+	1/16	18	1/288	0.33
P	1	31	1/31	3.06
PO_4^{3-}	1	95	1/95	1.00
COD (as O_2)	1/138	32	1/4416	0.022

* For NO_x an average value of 2 was used for x.

Figure 4-10 Table showing nutrification potentials for various nutrifying substances

Figure 4-10 shows the table with numbers for the different variables that can be inserted into the equations to produce final values for the eutrophication (or nutrification) potential.

In just a few pages, we have learnt a little about eutrophication. We have met different sciences such as biology and chemistry and we have seen that the growth of organisms can be affiliated to a few chemical compounds and reduced to a "simple" equation. However, we still do not know why this potential ended up in the Thiel article or why it is included in the method of life cycle assessment. To be quite honest, we do not know much about LCA at all yet. Since the Environment* so far seems rather uninhabited when compared with what pre-knowledge might suggest, it may be wise to look into the references on the environmental tool to check if more information is given on the Environment* there.

Life Cycle Assessment

The Thiel article refers to ISO standards connected to LCA methodology. Let us see what they contain. In the first ISO standard relating to LCA, ISO 14040 (1997), we are told:

> "LCA is a technique for assessing the environmental aspects and potential impacts associated with a product, by compiling an inventory of relevant inputs and outputs of a product system [and] evaluating the potential environmental impacts associated with those inputs and outputs" (p. vi).

This is further specified:

> "LCA studies the environmental aspects and potential impacts throughout a product's life (i.e. cradle-to-grave) from raw material acquisition through production, use and disposal. The general categories of environmental impacts needing consideration include resource use, human health, and ecological consequences" (p. vi).

We now know that the term 'life cycle' is referring to 'all the steps a product is involved in' and we also know that there are general environmental categories, but no information is given in the standard about what these general categories specifically encompass or how they can be measured. There is reason to believe that the three impact categories we met in the Thiel article are part of the "ecological consequences" category, but a warning is given a few lines below in the standard:

> "Results of LCA studies focused on global and regional issues may not be appropriate for local applications, i.e. local conditions might not be adequately represented by regional or global conditions" (p. viii).

Whether this is the case for the impact potentials we met in the Thiel article is not specified, but the authors did not specify any localities, so it might be reasonable to assume that the categories represent a regional or global dimension. Nevertheless, we would appear to need more information about global warming, acidification and eutrophication in order to make any certain statements in this respect.

> "LCA studies should systematically and adequately address the environmental aspects of product systems, from raw material acquisition to final disposal" (p.2)

Since the Thiel article is based on a study carried out in accordance with ISO 14040, we must presume that the categories given in the article are adequate for capturing the important environmental impacts. Figure 4-11 below shows the different phases of an LCA. Arrows going in both directions are illustrating that the method is iterative and the researcher (the one compiling the LCA study) is expected to go back and forth between the different steps.

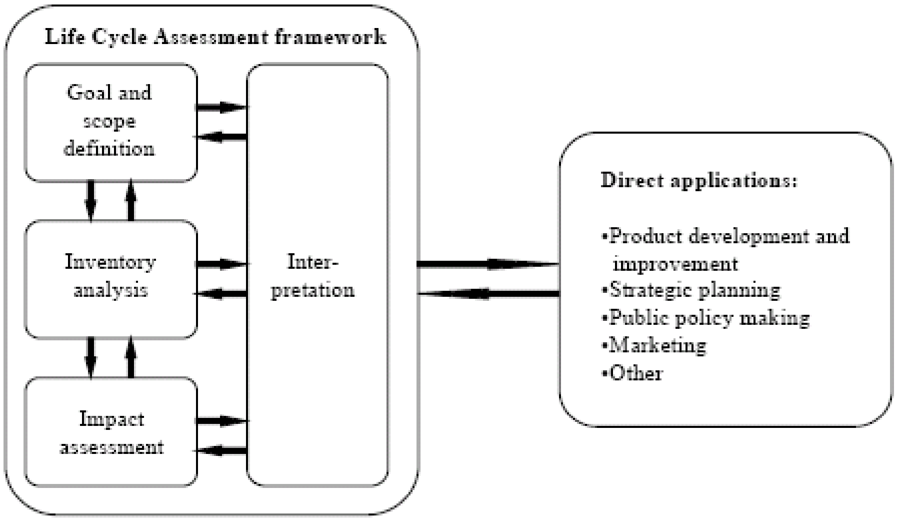

Figure 4-11 phases of an LCA (adapted from ISO 1998)

The diagram also makes it clearer why the Thiel article has been structured in its particular format with, for example, the names of the phases being used as headings in the article. The standard continues with descriptions of the specifics of the different phases and the word "environment" is included when you reach the chapter on impact assessment:

> "The methodological and scientific framework for impact assessment is still being developed. Models for impact categories are in different stages of development. There are no generally accepted methodologies for consistently and accurately associating inventory data with specific potential environmental impacts." (p. 5).

The standard explicitly states that the science is not "finished", and that we still need to wait for more accurate models of how the environment is affected by products' life cycles.

Perhaps more information about the environmental categories will be given in the other ISO reference, namely the ISO 14041 standard (ISO 1998). However, our expectations are lowered as soon as we start reading:

> "This International Standard [ISO14041] in addition to ISO 14040 specifies the requirements and the procedures necessary for the compilation and preparation of the definition of goal and scope for a Life Cycle Assessment (LCA), and for performing, interpreting and reporting a Life Cycle Inventory analysis (LCI)" (p.1).

The standard goes on to specify the steps necessary for creating an inventory – how to collect data, allocation procedures (i.e. how to share impacts between different outputs of a process), examples of data sheets etc. ISO 14041 gives no more information on environmental impacts. It does not tell us what data to collect, what substances to follow. However, the detailed specification of how to compile data adds credibility to the methodology. The standard itself, the procedures it contains and the examples it gives on datasheets are important actors in stabilising the "LCA actor-network."

4.1.2 The actor-network after the first round

After a search through the first tier of references (i.e. those directly linked to the article), our understanding of the Environment* and how it has come into being has not improved significantly. In fact, the environment appears to mostly be made up of equations, procedures and a few chemicals. Still, we have begun to appreciate that several sciences are involved and probably other spheres of activities as well, such as standardisation bodies and politics. Whether or not these are a part of science is open for debate, but in depicting the actor-network creating the Environment*, all the actors participating in stabilising truths count.

Apologies if this has bored you, either because you found the wording and the equations from the articles unnecessarily cumbersome or because you are all too familiar with the issues and regard it as trivial basic knowledge. Whatever the case may be, the quotes serve two main functions. The first is to show the outcomes of strings of translations, e.g. how the Greenhouse Warming Potential has been created by transforming nature and political decision-making into a single equation. The second function is presenting the technical language to display how a scientific language has been created to capture processes in nature. The number of words unfamiliar to an average reader indicates that there is a lot of work behind the creation of the Environment*.

What actors does the Thiel article depict so far? From the beginning (i.e. the Thiel article itself), we had emissions of CO_2, CO, NO_x and SO_2, we had Global Warming Potential, acidification potential and eutrophication potential, we had ISO and LCA, we had aluminium production, lightweight structures and recycling. Several new actors have been added after the first round: infrared radiation, IPCC, atmospheric lifetimes of chemical components, absorption capacities of chemicals, political decision-makers, chemical equations, an average algae, the atmosphere, water, soil, data collection procedures and a framework for conducting LCAs.

Figure 4-12 below is an initial drawing of what might be considered the actor-network of the Thiel article with its references.

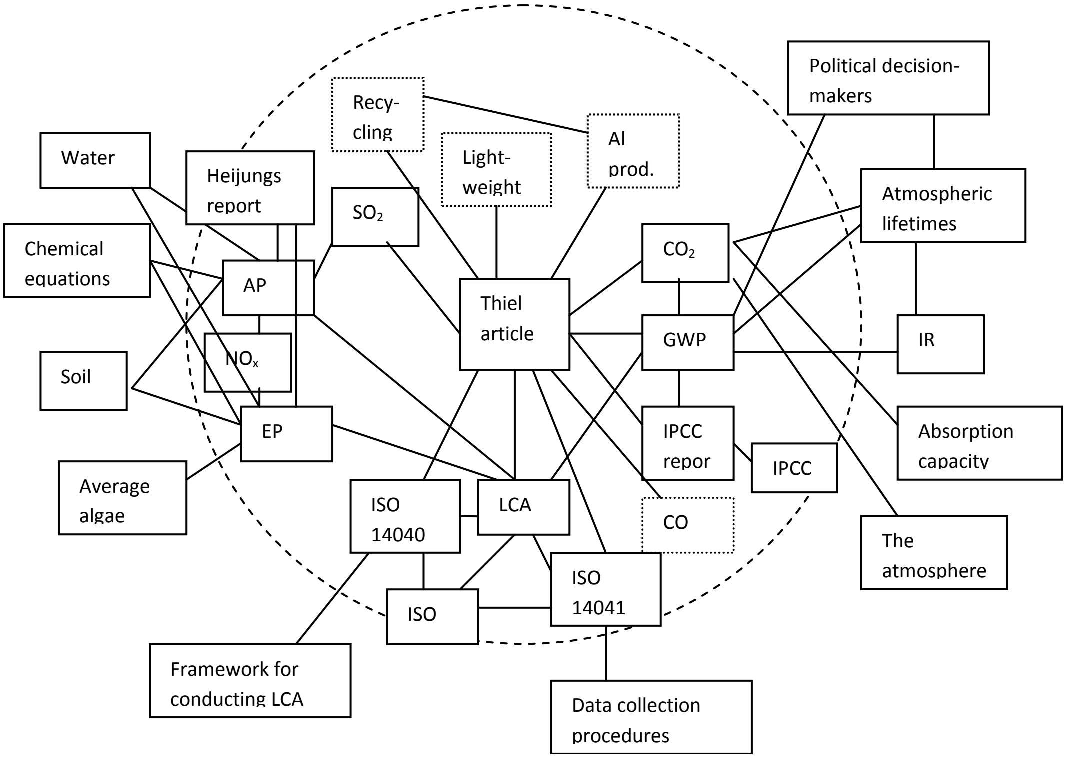

Figure 4-12 The actor-network, including the article and its references

The relative size of the boxes in the diagram is of no importance, all the boxes were just made small enough to fit in the diagram, but large enough to provide meaningful text. The circle indicates the jump between the actors appearing in the article and actors that have been included through the references. Boxes with dotted lines include actors that appear in the article, but which have yet to be explored. The whole diagram appears a little complex, but the Environment* seems to be missing. There are no or at least very few references to nature as we normally think of it, with its biological and physical resources. Nevertheless, there are already a substantial number of actors and links between them, indicating that there are connections to stabilise the actor-network and hence the truth of the claims in the Thiel article. We could have returned to the Thiel article to create solid lines in the dotted lined boxes, that is to capture information on those concepts that are introduced in the diagram but not yet discussed in the text. However, I want to check if the content of the impact categories can produce a picture of the Environment*. In other words, there is a need to move outside the first tier of references to see if we can find out what global warming, acidification and eutrophication really are and why they are deemed important enough to feature in the Thiel article.

4.2 The Environment* behind the equations

How can I even claim that the Thiel article has anything to do with the Environment* in the first place? The word "environment" is not mentioned in the title and the fact that the authors take the connection between life cycle assessment and the environment for granted does not make it a truth. I had prior knowledge of the LCA method and I knew it to be a widely accepted environmental assessment tool - thus I reacted to the title of the article. So here, in the second round, I will provide evidence for LCA being connected to the environment and for being connected to the automotive industry. The content of the three impact categories from the Thiel article will be scrutinised, as they should consist of the environment coupled to bumpers (i.e. the Environment*).

4.2.1 Second round: digging deeper into the environmental issues

It may seem rather confusing that I appear to be omniscient in this second round, given my ignorance in the preceding chapter. The reason is simply that, at first, I wanted to give you the feeling of the "black boxes", to show that the articles on environmental issues are packed with taken-for-granted truths. To reveal what the boxes actually contain demands a lot of work and extensive knowledge on a range of different subjects. If, however, this whole chapter is to be able to give a description of the Environment* at different times, I will have to speed up and jump from source to source without a thorough account of every connection that exists between them.[105] Publications printed after the year 2000 are only used if pointing to texts before the year 2000, as climate change will eventually come back into play towards the end of the chapter and because publications after the Thiel article cannot possibly have led to its initial stabilisation.

[105] However, I can assure the reader that all the articles presented in this round are somehow connected, either by referencing or being referenced by the Thiel article, one of its references or one of its references' references.

Global warming (or rather climate change) extended

The book employed in the previous round (Houghton et al 1994) has 339 pages with numerous references, tables, graphs, equations, maps and words describing the scientific working of the climate system and the relation between the climate system and atmospheric gases. However, it does not contain information on other aspects of nature or the consequences that may arise from changes in the composition of the atmosphere (i.e. the predicted direct effect of increased temperature). Fortunately, the passage in the IPCC book from 1994 on Global Warming Potential refers to another IPCC book from 1990 (IPCC 1990) with a broader scope. There we learn that the climate of the earth is determined by both natural and human factors. The most significant natural factor is the greenhouse effect. This refers to the mechanism whereby short-wave solar radiation passes through the atmosphere and heats the earth. The warm surface of the earth emits long-wave radiation and this is partially absorbed and re-emitted by gases in the atmosphere. There is no reason to doubt this, as the report clearly states: "The greenhouse effect is real; it is a well understood effect, based on established scientific principles" (ibid. p. xiv). Figure 4-13 below shows an energy balance for the incoming solar radiation and the radiation emitted from earth.

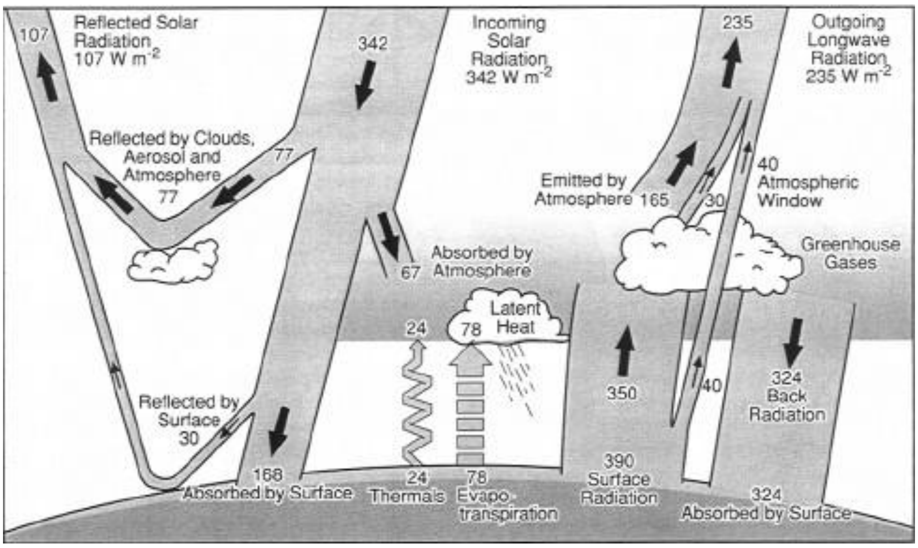

Figure 4-13 The greenhouse effect and the energy balance (Trenberth et al 1996)

The earth is a greenhouse, although the walls and the roof are made of gases, not glass. Gases that let the solar rays in, but do not allow heat to escape. Repeatedly we are told that without this effect, life on earth could not be sustained. What should worry us is the enhanced greenhouse effect, the building of stronger walls and roof from anthropogenic sources, that traps more and more heat inside.

It seems that the greenhouse effect has been there since time immemorial, but for how long has the enhanced greenhouse effect, the global warming caused by anthropogenic sources, existed? There are good reasons for stating that global warming became fact in 1988. In that year, Jim Hansen stated before the US government that: "It's time to stop waffling, and say that the evidence is pretty strong that the greenhouse effect is here" (Hansen 1988). It was also the year that the Intergovernmental Panel on Climate Change (IPCC) was established in a joint effort by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). Lastly, it is the year that Spencer Weart uses to separate the more random approaches from the systematic building of a scientific project in the history of climate change.[106]

This is not to make you believe that climate change due to human activities is entirely attributable to one individual and a large organisation. There are also other contributory factors, with actual temperature, actual emissions and computer models being among the most important.

> "Attention has focused throughout the world on projected climatic change because of fears of potentially far-reaching consequences of a drastic warming and associated sea level rise. This threat has been associated primarily with the developed countries' heavy use of fossil fuels whose burning releases carbon dioxide, a greenhouse gas which spreads quite evenly in the global atmosphere. The 1980s were for whatever reasons an unusually warm decade, following a cooler period that had culminated in the early 1970s, stimulating many assertions that anthropogenic global warming was now evident.
> From 1970 to the early 1990s, world fossil fuel-related emissions of CO_2 grew by 50 percent, about as much as population, so that per capita emissions have remained level. Meticulous measurements document a worldwide rise in atmospheric CO_2 of about 10 percent in the same period, and concentrations will continue to rise even if emissions flatten, because of the time required for the land and sea to absorb carbon." (Ausubel et al 1995).

Although much of the science had already been produced prior to 1980, it had not created a stable actor-network with the single idea that human beings affect the weather and the temperature of the globe through emissions of

[106] The work by Weart (2007) has been useful for finding references and obtaining an overview of climate change science.

CO_2. Weart (2007) states that there was no great momentum behind the idea up to and even during the 1970s:

> "Few scientists [were] centrally concerned with CO2 as an agent of future global warming. They addressed the gas as simply one component in their study of biological, oceanographic or meteorological systems (Hart & Victor 1993). Most stuck with the old assumption that the Earth's geochemistry was dominated by stable mineral processes, operation on a planetary scale over millions of years. People did not easily grasp how sensitive the Earth's atmosphere was to biological forces – the totality of the planet's living activity – to say nothing of the small fraction of that activity affected by humanity"

That several scientists involved in climatic research doubted human influence in the 1970s is accentuated by the writings of several commentators:

> "To date on the hemispheric and global scales, a "signal" of man-made climatic change has not yet been separated from the "noise" of natural climatic variations"(Landsberg 1970).

With a graph showing temperatures compared to one showing annual precipitation for Philadelphia in the years between 1738 and 1967, Landsberg claimed that randomness was the case. Two years later, Lowry (1972) expanded Landsberg's arguments while leaving room for humans to affect the climate in the longer term:

> "These [climate] models and discussion, though incomplete, provide grounds for three important conclusions: (1) Single-factor reasoning about global effects of air pollution on climate is usually misleading. (2) Natural variations in basic climatic parameters and natural concentrations of certain air pollutants are distinctly greater than those attributed to man's activities (Bryson & Wendland 1970; Landsberg 1970; Mitchell 1970; Robinson 1970). (3) Important changes in global climate may be related to effects of air pollutants on mid-latitude storminess. These changes are not related to such measures as the mean temperature of the earth's surface. At present it appears that our knowledge of the complex earth-atmosphere system and of the values of critical parameters is so scant as to make any definitive statements about the climatic effects of air pollution impossible for at least a decade hence. None the less, we should not overlook the strong possibility that man's less-than-global, but more importantly non-random activities, such as urbanization and concentrated industrialization, may have greater longterm effects-because of their non-randomness-than do nature's larger, but random, variations"

Finally, Mason (1976) stated:

> "The climatic system is so robust… that man has still a long way to go before his influence becomes great enough to cause serious disruption."

Of course, such statements were not made in a vacuum. They would never have been made if there were not already a concern that the climate was indeed changing and that man was involved. Svante Arrhenius (1896) first proposed the idea that an increase in carbon dioxide in the atmosphere could lead to global warming, but more from an interest in what was causing ice ages than a concern that human beings could seriously alter the environment. The idea was not taken up again before Callendar (1938) published an article containing a graph that showed how the earth had become warmer between 1880 and 1930 – a period in which the CO_2 level in the atmosphere was also increasing. The graph is shown in Figure 4-14. Although Callendar's work was acknowledged, most scientists believed that natural variations were the issue and that nature's ability to handle increased levels of CO_2 in the atmosphere was great enough to cancel out any human-induced temperature rise (Weart 2007).

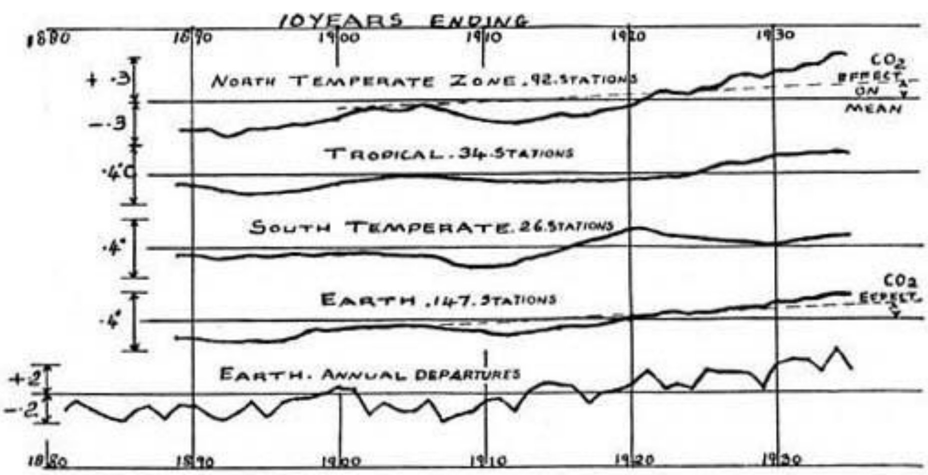

Figure 4-14 Callendar's graph of increasing temperatures and CO_2 levels

Callendar's work did not lead to a great revival for Arrhenius' theory, but during the decades between 1940 and the late 1990s, several discoveries were made, measuring equipment was manufactured, sciences were coupled and hypotheses tested. For instance, laboratory studies showed that the absorption spectra of water and carbon dioxide were not overlapping in the atmosphere, although they are on the ground. Then there were drilling techniques, the use of the isotope Carbon 14 to track CO_2 in the atmosphere, expeditions to remote places and measurement techniques for temperature at earlier ages. These elements were brought together in a graph presented by Barnola et al (1987) as shown in Figure 4-15.

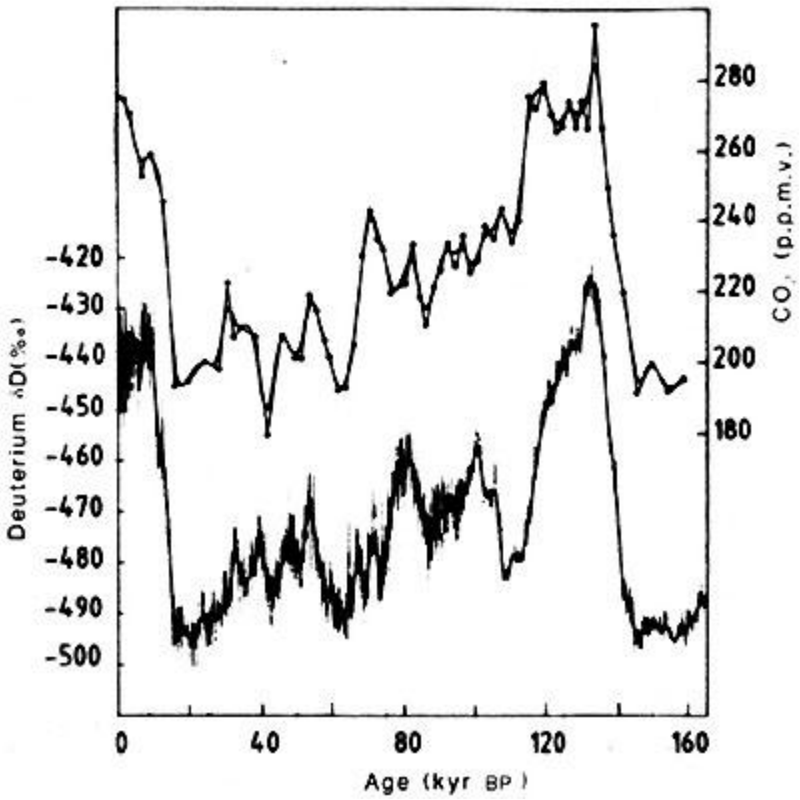

Figure 4-15 Relationship between CO_2 concentrations and temperature ***(****Barnola et al 1987****)***

The upper curve shows CO_2 concentrations in parts per million, while the lower curve is a reconstruction of atmospheric temperature from measurements of the isotope deuterium. The X-axis is Age given in thousands of years before the present day (BP) (with the present day at the far left). This graph was also important in establishing climate change as a real issue in 1988, as its visual effect makes the connection between temperature and CO_2 levels so apparent. The time scale and the "hard" science behind the graph reinforced the "real" nature of the issue.

Thus, it all began with rather simple measurements with simple technologies. Such measurements and technologies were still important in the IPCC publication (1990) and gathering them in a disciplined way was still proving challenging:

> "Changes in [weather] station environment can seriously affect temperature records (Salinger 1981). Over the years, stations often have minor (usually under 10 km) relocations and some stations have been moved from rooftop to ground level. Even today, international practice allows for a variation of thermometer heights above ground from 1.25 to 2 metres. Because large vertical temperature gradients exist near the ground, such changes could seriously affect thermometer records…[A bias] on the large scan can emerge when the character of the changes is not random. An example is the systematic relocations of some observing stations from inside cities in many countries to more rural airport locations that occurred several decades ago. Because of the heat island effect within cities, such moves tend to introduce artificial cooling into the climate record. Jones et al.(1986) attempt in some detail to adjust for station relocations when these appear to have introduced a significant bias in the data but Hansen and Lebedeff (1987) do not…[All] depend on denser network of stations than are usually available except in the USA, Europe, the Western Soviet Union and a few other areas" (Folland et al 1990).

It is vital to get the techniques under control, for example having the thermometers at the right elevation without systematic flaws, as the global warming effect cannot be seen in one single place. I am not speaking of the effect *of* global warming but global warming as an effect itself. Whilst every single weather station in the world may show random results, it is when the results of all these weather stations are put together (i.e. temperature measurements from all the weather stations) that a global temperature increase can be observed. However, such simple technologies and measurements have also been coupled with complex computer models that try to capture different processes on earth (and their interactions) in order to predict future climate changes. Figure 4-16 shows an example of variables included in such a simple model.

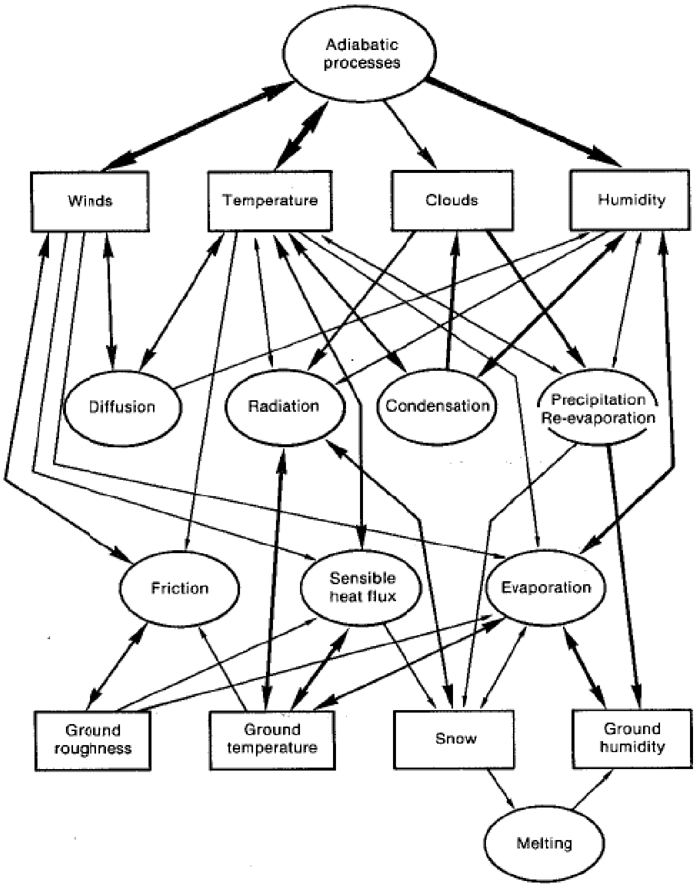

Figure 4-16 Parameters in a simple model of the climate (Houghton 1984)

Some of the different processes involved in determining the climate and the interactions between them are depicted here. The thickness of the arrows indicates the strength of the interactions. Even this simple diagram reveals many of the interconnections between different entities on Earth and in the atmosphere, and the environment seems much closer. When we understand that these processes are also connected to grid maps of the actual Earth (or at least representations of it), the environment comes even closer:

> "General circulation models are based on the physical conservation laws which describe the redistribution of momentum, heat and water vapour by atmospheric motions. All of these processes are formulated in "primitive" equations, which describe the behaviour of a fluid (air or water) on a rotating body (the Earth) under the influence of a differential heating (the temperature contrast between equator and pole)

caused by an external heat source (the Sun). These governing equations are non-linear partial differential equations, whose solution cannot be obtained except by numerical methods. These numerical methods subdivide the atmosphere vertically into discrete layers, wherein the variables are "carried" and computed. For each layer the horizontal variations of the predicted quantities are determined either at discrete grid points over the Earth, as in grid point (finite difference models), or by a finite number of prescribed mathematical functions as in spectral models. The horizontal resolution of a typical atmospheric model used for climate studies is illustrated by its representation of land and sea shown in Figure 3.4." (Cubasch & Cess 1990, p. 84)

Here, nature really becomes visible. The rotating Earth with its cold pole and hot equator and the Sun are described, although merely in order to be translated into equations suitable for modelling. Figure 3.4 from the book is reproduced below in Figure 4-17.

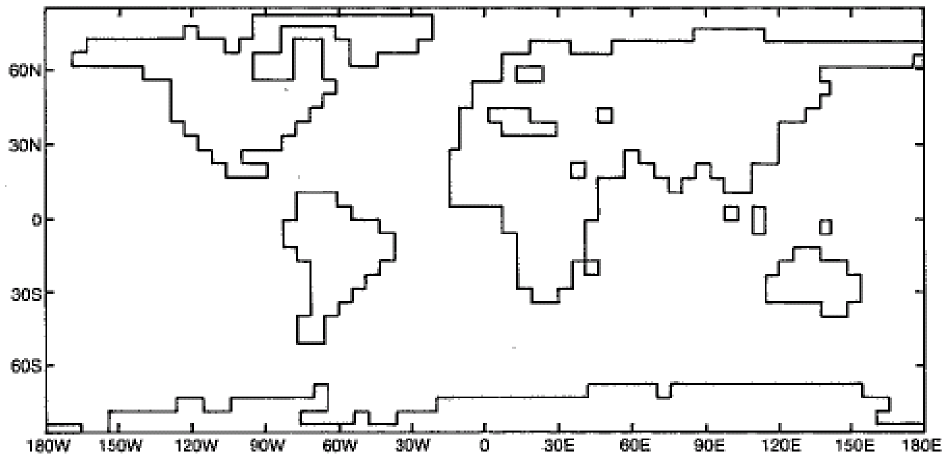

Figure 4-17 This is Figure 3.4. from (Cubasch & Cess 1990: 84): the model land-sea mask for a typical climate model.

The diagram looks familiar. It immediately creates associations with world maps and gives the impression that the modellers can actually tell us something about the Earth. However, as with the issue of achieving scientific discipline in temperature measurements, there are a few problems with the computer models:

"Unfortunately, even though this is crucial for climate change prediction, only a few models linking all the main components of the climate system in a comprehensive way have been developed. This is mainly due to a lack of computer resources, since a coupled system has to take the different timescales of the sub-system into account, but also the task requires interdisciplinary cooperation.

An atmospheric circulation model on its own can be integrated on currently available computers for several model decades to give estimates of the variability about its equilibrium response; when coupled to a global ocean model (which needs millennia to reach an equilibrium) the demands on computer time are increased by several orders of magnitude. The inclusion of additional sub-systems and a refinement of resolution needed to make regional predictions demands computer speeds several orders of magnitude faster than is available on current machines" (Cubasch & Cess 1990: 89).

The computer models are used to predict future temperature changes, as well as other changes on Earth (depending on which variables are held constant). However, even though the IPCC report (1990) is broader in scope than the publication from 1994 (Houghton et al, 1994), the emphasis is on geophysical changes such as temperature rise, sea level rise and the melting of ice and snow. The same picture is drawn in an LCA related publication from 2005:

"The possible consequences of the greenhouse effect include an increase of the temperature level leading to increased temperatures in the oceans and melting of the polar ice caps and glaciers in mountain areas, resulting in elevated sea levels. The increasing temperature level may also result in regional climate changes". (Stranddorf et al 2005)

The same question as posed in the 1970s is worth repeating: "Does this give any reason for concern?" There is a short text devoted to effects on ecosystems in the IPCC report from 1990, but the conclusions are vague, with wording that indicates a high degree of uncertainty. It gives no clear-cut answers as to whether climate change would affect ecosystems positively or negatively (Melillo et al 1990). In the updated reports from 1995, we meet the same uncertainties regarding effects on ecosystems, but we are also faced with other direct and indirect consequences for human beings due to increases in CO_2, temperature and sea level (Watson et al 1995):

"A number of studies have evaluated sensitivity to a 1m sea level rise. This increase is at the top of the range of IPCC Working Group I estimates for 2100; it should be noted, however, that sea level is actually projected to continue to rise beyond 2100. Studies using this 1m projection show a particular risk for small islands and deltas. Estimated land losses range from 0.05% for Uruguay, 1% for Egypt, 6% for the Netherlands and 17.5% for Bangladesh to about 80% for the Majuro Atoll in the Marshall Islands, given the present state of protection systems. Large numbers of people also are affected; for example, about 70 million each in China and Bangladesh. Many nations face lost capital value in excess of 10% of their gross domestic product (GDP). Although annual protection costs for many nations are relatively modest (about 0.1% of GDP), the average annual costs to many small island states total several percent of GDP. For some island nations, the high cost of providing storm surge protection would make it essentially infeasible, especially given the limited availability of capital for investment" (Watson et al 1995, p. viii)

If the prospect of a rising sea does not scare you, there are other health-related effects that may:

"Climate change is likely to have wide-ranging and mostly adverse impacts on human health, with significant loss of life. These impacts would arise by both direct and indirect pathways (Figure 3) and it is likely that the indirect impacts would, in the longer term, predominate.

Direct health effects include increases in (predominantly cardio respiratory) mortality and illness due to an anticipated increase in the intensity and duration of heat waves. Temperature increases in colder regions should result in fewer cold related deaths. An increase in extreme weather would cause a higher incidence of death, injury, psychological disorders and exposure to contaminated water supplies.

Indirect effects of climate change include increases in the potential transmission of vector borne infectious diseases (e.g., malaria, dengue, yellow fever and some viral encephalitis) resulting from extensions of the geographical range and season for vector organisms. Projections by models (that entail necessary simplifying assumptions) indicate that the geographical zone of potential malaria transmission in response to world temperature increases at the upper part of the IPCC projected range (3-5°C by 2100) would increase from approximately 45% of the world population to approximately 60% by the latter half of the next century. This could lead to potential increases in malaria incidence (on the order of 50-80 million additional annual cases, relative to an assumed global background total of 500 million cases), primarily in tropical, subtropical and less well protected temperate zone populations. Some increases in non-vector borne infectious diseases - such as salmonellosis, cholera and giardiasis - also could occur as a result of elevated temperatures and increased flooding.

Additional indirect effects include respiratory and allergic disorders due to climate enhanced increases in some air pollutants, pollens and mold spores. Exposure to air pollution and stressful weather events combine to increase the likelihood of morbidity and mortality. Some regions could experience a decline in nutritional status as a result of adverse

> impacts on food and fisheries productivity. Limitations on freshwater supplies also will have human health consequences" (Watson et al 1995, p. 10).

Finally we see good reasons for caring about climate change and why it is included in the Thiel article. With such devastating consequences and with CO_2 as a main contributor, cars should really be made lighter.

We have now encountered the entire Earth, made up of numerous locations for temperature measurements, and can see that it is a place that gets warmer. We have met ocean currents, glaciers, snowcaps, several large organisations with thousands of scientists, plant species, diseases, deaths from heat waves and decreases in cold-related deaths

Acidification

In the first round, we learnt that acidification could be translated and reduced into a single equation, explaining the potential of different chemical compounds to create a lower pH in deposits into water and soil, measured in the amount of protons (H^+). The only reference found in Heijungs et al. (1992) was to a Dutch text book by Vermeire (1992), a text book that I was unable to get hold of and that would probably have told me very little, considering my rather limited knowledge of the Dutch language. We must move elsewhere to see if we can find out what acidification really is.
An article by Gorham (1998) gives an overview of research on acidification and guides the search for the actors that make up the acidification actor-network. He writes:

> "Research on acid deposition can be traced to the mid-19th century, but has expanded greatly in the last 50 yr, focussing in particular upon the effects on ecosystems of acid deposition caused by the combustion of fossil fuels. Observational studies first associated such acidification with its chemical and biological effects. They were supplemented in 1976 by experimental acidification of a whole lake. By 1980, paleological techniques were employed to investigate past histories of acidification. In the 1980s, critical loads were calculated to measure how much acid deposition could be tolerated by aquatic ecosystems. Reductions in emissions of sulphur dioxide, as well as experimental studies in the mid-1980s, allowed investigations of recovery from acidification…in the mid-1990s, it has become apparent that acid deposition interacts with other environmental stresses such as climate warming and ozone depletion." (p. 153)

This provides us with a short history of development of acidification through science, but it does not state what effects acid deposition may have. Let us see if we can understand more about acidification by looking at what an LCA reference tells us about the problem:

> "Acidification is a local and regional effect…[In] the terrestrial ecosystem the effects are seen in softwood forests (e.g. spruce) but also in hardwood forests (e.g. beech) as inefficient growth and as a final consequence dieback of the forest. These effects are mainly seen in Scandinavia and in the middle/eastern part of Europe. In the aquatic ecosystem the effects are seen as clear acid lakes without any wildlife. These effects are mainly seen in Scandinavia. Buildings, constructions, sculptures and other objects worthy of preservation are also damaged by e.g. acid rain" (Stranddorf et al 2005).

Different trees are mentioned in this reference, together with lakes and buildings. Moving to another reference, the geography becomes even more specific (Colvile et al 2001, p. 1542):

> "In the 1970s, it was suddenly noticed that trees were apparently dying en masse in the highly polluted "Black Triangle" of East Germany, the Czech Republic and Poland (Bach 1985; Kandler & Innes 1995; Ulrich 1990) and number of dead fish floated to the surface of Swedish rivers and lakes (Borg 1986) as well as in similar North American environments (Driscoll et al 1980)". (Colvile et al. p. 1542)

Countries are specified and the presence of a number of dead fish makes acidification more frightening and more real than just "a clear acid lake without any wildlife". During the 1970s and early 1980s, a range of articles by Scandinavian researchers (e.g Bell 1981; Nicholson 1978; Nordo 1976; Wright & Henriksen 1978) were devoted to the detrimental effects of acidification on water bodies, especially the death of fish - with trout and salmon being among the researched species . Linthurst et al (1986) state that statistically reliable estimates of the regional effects of acidification on ecosystems have been gathered for lakes in the United States. Although some of these researchers also studied effects on forest vegetation (e.g. Abrahamsen et al 1977), it was hard to find evidence of effects on terrestrial ecosystems, i.e. effects from deposits on soil. This is emphasised by Evans (1982):

> "No general conclusions can be drawn about the effects of current levels of precipitation acidity on plant pathogen-host interactions under field conditions. Few experiments have been aimed at determining the impacts of acidic precipitation on crop and forest yields. Most of these studies are inadequate because they are not conducted in nature with adequate randomization of treatments coupled with vigorous statistical analyses. From the above information, it must be concluded that research on the effects of acidity in precipitation on terrestrial

vegetation is too meager to draw definitive conclusions about the effects of ambient and/or anticipated levels of acidity"

The way to find out if water or soil is acid is through various techniques for measuring pH (Marinenko & Koch 1984). Such studies range far back in time - for example, in 1920, Wherry discusses how acidity in the soil can be measured and lays out several methods for establishing the pH of soil (Wherry 1920). Figure 4-18 shows the indicators he found useful.

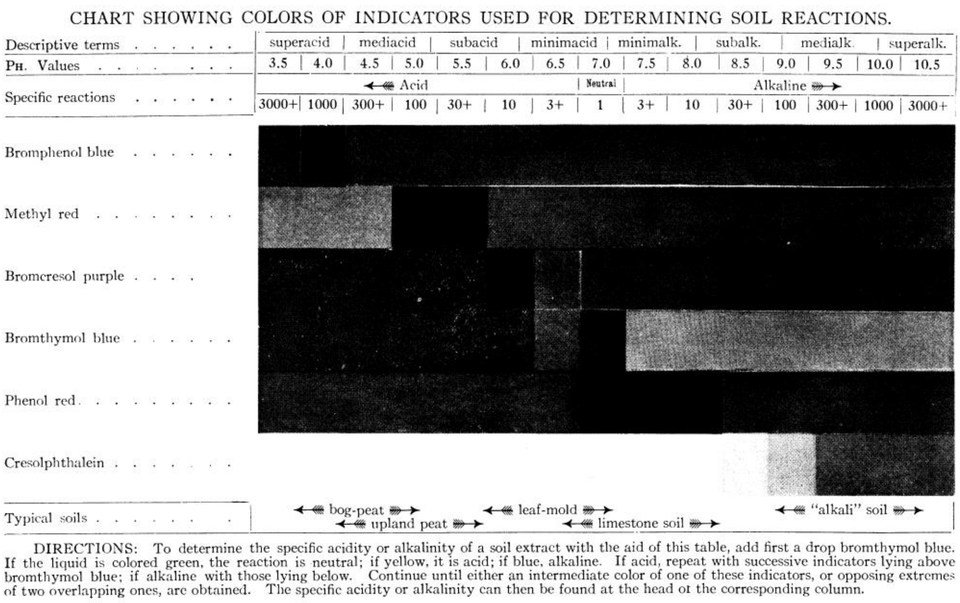

Figure 4-18 Chart showing different indicators for measuring pH in soil

By using chemical substances that react and change colour according to the amount of H+ ions, it is possible to translate the condition of the soil first into a colour and then into a single number. Such techniques are still employed, although automatic monitoring of pH was introduced in the late 1960s (Henriksen & Selmerol 1970).

From the late 1970s, computer modelling became more and more widespread in relation to acidification, used to predict future scenarios and to keep track of the data that had been gathered. Henriksen (1980) made an empirical titration model based on regional water-chemistry data for more than 700 lakes in Norway, followed by the Birkenes model (Christophersen & Wright 1981) that included both hydrology and chemistry. During the 1980s, models also began to track the emissions of acidifying substances, with the RAINS model being one of the more important (Alcamo et al 1987; Alcamo et al 1990; Galperin et al 1995).[107] The first editions of the model emphasised "the transboundary aspects of the acidification problem…[Linked] submodels are available for SO2 emission, costs of control strategies, atmospheric transport of sulphur, forest soil and groundwater acidity, lake acidification, and the direct impact of SO2 on forests" (Alcamo et al 1987). As the citation shows, the model also included the costs of control strategies. Thus, acidification is also included in other activities and, according to Alm (1997), scientists were also leading the political agenda:

> "Scientists were the first to define acid rain as an environmental problem, and they set the context in which the debate took place (Cowling 1982, 115A). In fact, the acid rain issue came into prominence only because scientists and researchers kept telling the world of the potential devastating effects of acid rain (Schmandt & Roderick 1985)"

One of the inventions of scientists involved in deposition of sulphur and nitrogen oxides was the definition of a "critical load." According to Lidskog and Sundquist "Canadian scientists introduced the concept of critical loads in 1974 and subsequently this was developed further by Scandinavian scientists." The most widely cited definition comes from Nilsson and Grennfelt (1988), which says that critical load is "[a] quantitative estimate of exposure to one or more pollutant below which significant harmful effects on specified sensitive element of the environment do not occur according to present knowledge"(Nilsson & Grennfelt 1988). Critical loads became a tool for scientists studying different regions, as well as for politicians trying to enforce regulation. Combining these efforts with the previously mentioned models leads to the production of critical load maps of different regions, as shown in Figure 4-19.

[107] RAINS is an abbreviation for '**R**egional **A**ir Pollution **IN**formation and **S**imulation'

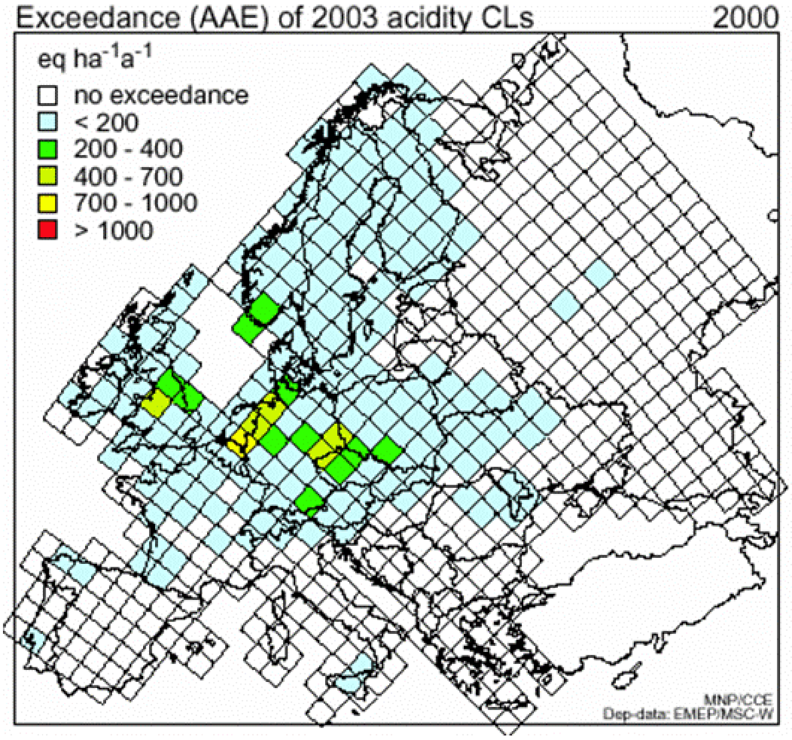

Figure 4-19 Map of exceedance of critical loads in Europe (from Slanina 2006)

The map shows how the environment is almost captured in terms of both the totality and the specific sites. However, the grid size is too large for the actual rivers, trees and fish to make their presence felt.

Several articles (Ausubel et al 1995; Colvile et al 2001; Heinen & Low 1992; Likens et al 1972) mention emissions from automobiles as a source of NO_x leading to acidification. That may explain why acidification ended up in the Thiel article in the first place.

Finally, acidification can also be linked with other environmental issues:

> "It has recently become apparent that acid deposition interacts with other environmental stresses to damage ecosystems. One interesting example is the penetration of biologically harmful ultraviolet radiation into lakes and streams. Two research groups have shown such penetration to be enhanced not only by depletion of stratospheric ozone but also through reducing concentrations of dissolved organic matter

that absorbs such radiation, by acid deposition and the climatic warming observed in Ontario in recent decades" (Gorham 1998, p. 160). [108]

Acidification is suddenly connected to climate change, not only through LCA but also even more directly as they "work" together to increase the damage from ozone depletion. We meet climate change again and we also meet water bodies, a number of fish, trees, pH measurements, critical loads and even automobiles.

Eutrophication

When starting to nest backwards to find the actors in the eutrophication actor-network, it soon became evident that the world is not organised according to the LCA impact categories. In fact, researchers often treat acidification and eutrophication simultaneously, which is not really all that strange, considering that they are both coupled to local and regional impacts, both affect soil and water, and both have NO_x as an active gas (Bouwman et al 2002; Kuylenstierna et al 1998; Posch et al 2001; Zak & Beven 1999). Hence, many of the actors acting to stabilise the acidification actor-network are also acting on behalf of eutrophication, such as critical loads (Nilsson & Grennfelt 1988), the RAINS model (Alcamo et al 1987) and NO_x itself.

However, acidification and eutrophication part company when it comes to impacts. Whereas the former creates clear water bodies, the latter creates excess growth and fish struggle as the oxygen level in the water becomes too low. These effects have been recognised and observed for a long time (Hasler 1947; Lindeman 1942). The terrestrial effects (i.e. on soil and not in water) of eutrophication are harder to measure, after all few deaths are observed. Instead there is a problem of loss of diversity, as some plants are given better conditions for growth.[109]

To capture differences between plants and between ecosystems, Grennfelt and Thörnlöf (1992) use the concept of "limiting nutrient". A concept that goes far back in time and is often referred to as Liebig's Law of the

[108] Gorham (1998) also makes a comforting remark for anyone who is struggling to trace the actor-networks of environmental problems: "Another lesson to be learned is that scientists (including this author) often do not take the time to search adequately the earlier research literature, so that they 'discover', time and again, what is already known. Exponential increase in the number of scientific articles published each year makes such a search ever more difficult, despite the availability of computerized techniques."

[109] The LCA guide from Leiden (Heijungs et al, 1992) also has a category for biodiversity and, if eutrophication is also to be associated with the species that survive, it becomes hard to keep the categories separated.

Minimum (Liebig 1840). It says that the total of resources available does not control growth, but rather it is the scarcest resource that will do so. The concept of limiting nutrient makes sense; it is almost intuitive. If I am dying from thirst, more biscuits or a new car won't help me. However, there may be problems associated with this concept. In the words of Finnveden and Potting (1999):

> "The concept of "the limiting nutrient", however, is a simplification and can be misleading. Examples of complications are that the limiting nutrient may change over seasons. The limiting nutrient may also change over the years, for example as an effect of earlier loadings. The balance between different nutrients is also of importance. Since different species have different nutrient requirements, different species may be limited by different nutrients. A change in the balance between nutrients may therefore lead to a shift in species composition. Another important aspect is the possibility of the transportation of nutrients from one ecosystem to another one. Thus, even if a nutrient is emitted to an ecosystem where it has no impact, it may be transported to another ecosystem where it can have an impact. It might therefore be that the contribution for an emission to eutrophication is always larger than zero" (pp. 311-312).

Just when the world had been made simple and understandable, we are told that there are complicating factors. We can no longer be sure whether emissions associated with eutrophication will have an impact or, if they do, where or when this impact will take place.

Such aspects make it difficult to understand what eutrophication really means, a difficulty that is emphasised by Finnveden and Potting (1999):

> "Eutrophication is a difficult impact category for several reasons. Substances that may cause the impact can be emitted to both air and water. Impacts can occur in many different types of terrestrial and aquatic systems. The fate processes are site dependent as are the impacts. The fate processes depend on different characteristics of the emitting source, environmental media, and receiving environments. The impacts depend on background loads and different sensitivities of different ecosystems. As discussed below, different nutrients may limit the growth in different ecosystems. Another complicating factor is that some impacts, e.g. increased growth, in some cases may be regarded as a positive impact rather than a negative one." (p. 311).

Perhaps the transition from speaking of acidification and eutrophication to focussing solely on NO_x emissions would make this simpler. We no longer need to worry about the actual end points and eventual effects; instead, we can concentrate on the source of emissions.

LCA

Before examining the details of LCA, it's time for a short detour to demonstrate that the use of LCA on car parts is actually performed and presented by authors other than Thiel and Jenssen. In the same year (i.e. 2000), Saur et al. published an article on LCA for different materials for fenders. By looking at this article, we may perhaps also be able to see whether or not the conclusions in the Thiel article are only based on biased researchers, that is, on the fact that these researchers want to promote the use of aluminium. Examining the article by Saur et al. (2000) reveals that this may indeed be the case. In the latter article, the authors examine 5 different materials for fenders - three injection-moulded polymer blends, as well as steel and aluminium. The article looks at 12 different environmental impact categories:

1. Energy use [MJ]
2. Resource use [scarcity units]
3. Water use [m^3]
4. Global Warming Potential (GWP, [GHG-eq])
5. Ozone Depletion Potential (ODP, [CFC-eq])
6. Acidification Potential (AP, [SO_2-eq])
7. Eutrophication Potential (EP, [phosphate-eq])
8. Photochemical Ozone Creation Potential (POCP, [ethene-eq])
9. Human toxicity, air (Htox air, [Htx-eq])
10. Human toxicity, water (Htox water, [Htx-eq])
11. Ecological toxicity (Eco tox, [ETX-eq])
12. Waste [t]

Suddenly potential impacts to the environment are multiplied. We are no longer faced with only three categories (although the word 'only' may be an understatement, as we have seen that these three are fairly complex categories) – now we have four times as many. Even though the article by Saur et al (2000) makes connections to a "total" environment - to all possible environmental effects inflicted by the different material choices and the production, use and end-of-life stages - it is still the climate change category that is emphasised. The other categories seem to be included just to show that they have been calculated.

What about the results? Aluminium is worse than steel in all but four categories. That even includes the global warming potential. We may have experienced a fraud. The Thiel article seemed to have stabilised the idea of the aluminium bumper carrier as being more environmentally friendly, but how can it be if aluminium is in fact the more environmentally *un*friendly material for fenders? Might it be due to different data sources? Perhaps.

However, we are comforted when we reach the end of the article. While discussing the limitations, we are told that "life cycle studies depends on spatial differences, which need to be carefully analyzed (i.e. if spatial models that omit non-acidifying emissions over sea were used for modelling acidification contributions, aluminium would show a much better performance." This is a relief and further comfort is soon given: "System boundaries and assumptions influence the results of life cycle considerations. They have to be set carefully (e.g. if recycled material had been a consideration, aluminium would have been the favourable design!)" Phew!

Aluminium is still the better material, at least if recycled. We must therefore explore the recycling path (i.e. information that tells us how recycling makes for better environmental performance). Before going there, however, we must take a closer look at the LCA method itself and what it tells us about the Environment*.

Both the Thiel article and the Saur article refer to ISO standard 14040, but the Saur article also introduces another ISO standard, namely ISO 14042 (ISO 2000), which brings us closer to the environment. The standard describes the model for assessing environmental impacts and begins with:

> "Life cycle impact assessment, LCIA, is the third phase of life cycle assessment described in ISO 14040. The purpose of LCIA is to assess a product system's life cycle inventory analysis (LCI) results to better understand their environmental significance. The LCIA phase models selected environmental categories, called impact categories, and uses category indicators to condense and explain the LCI results. Category indicators are intended to reflect the aggregate emissions or resource use for each impact category. These category indicators represent the "potential environmental impacts" discussed in ISO 14040" (ISO 1998, p. v).

The LCIA is based on some concepts that need to be defined, as indeed they are later in the same document (ISO 1998, p.2). One such is an *impact category*, defined as a "class representing environmental issues of concern to which LCI results may be assigned," the second is a *category endpoint*, defined as an "attribute or aspect of natural environment, human health or resources, identifying an environmental issue of concern," and the third is an *environmental mechanism*, defined as a "system of physical, chemical and biological processes for a given impact category, linking the LCI results to category indicators and to category endpoints". These concepts are essential detrimental for calculating the environmental impacts for products as shown in Figure 4-20 with acidification as an example.

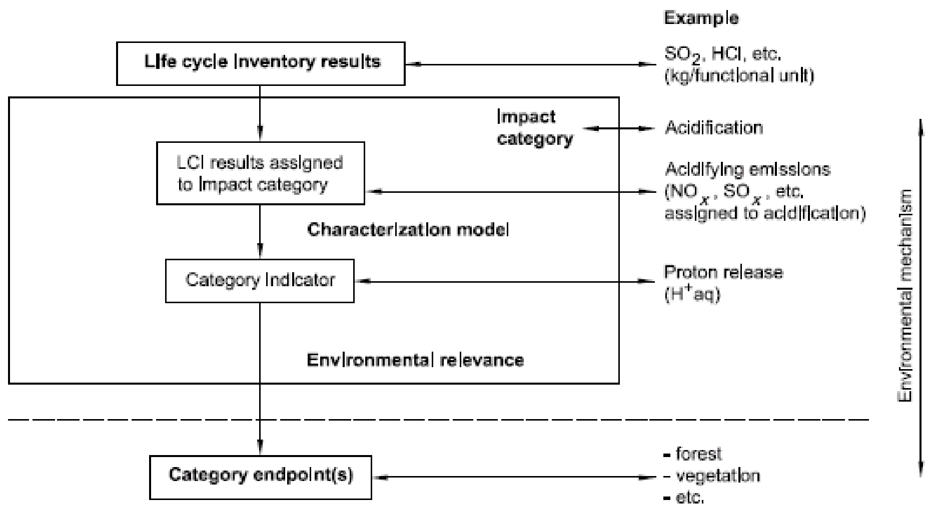

Figure 4-20 The concept of impact categories and category indicators

The results from the inventory are connected to an environmental issue of concern through the impact category. We have to be cautious, however, because the category indicators neither depict the actual concerns nor do they take the specificities of the environment into concern:

> "LCIA typically excludes spatial, temporal, threshold and dose-response information, and combines emissions or activities over space and/or time. This may diminish the environmental relevance of the indicator result…LCIA results do not predict impacts on category endpoints, exceeding of thresholds, safety margins or risks" (ibid. p. 10).

As we have seen for acidification and eutrophication, much research effort has been put into the spatial, threshold and dose-response issues. The concept of critical loads was important in establishing measures to manage emissions related to the categories and also to understand how the environment varies in different places. This is, as we now are told, not taken into account in an LCA. Although acidification and climate change (with references to IPCC) are mentioned, the standard does not explicitly offer a list of impact categories, nor does it give anything other than a few examples of chemical components that may be assigned to various categories.

Referring to the ISO standards was therefore a dead end, in the sense that there are no roads leading from the ISO standards and they have no references except to other ISO standards in the 14040 series. They are almost perfect black boxes, as all the information is condensed and presented in an objective manner. Searching for the actors (both human and other) that the standards comprise leads us the ISO web page (www.iso.org), where nothing other than sales information is to be found in relation to the relevant ISO standards, together with a brief note that Sub-Committee 5 under Technical Committee 207 (TC207/SC5) is responsible for the development of standards on life cycle assessment. Trying to unveil the secrets of TC207/SC5 brings us to TC207's web page (www.tc207.org) but again we get no further, as there are no accessible documents, no information on the history and developments of LCA, no references and no actors. However, on the ISO web pages we learnt that ISO is a worldwide organisation for the development of standards and has a strategic partnership with the World Trade Organization (WTO). That does not tell us much more about the environment, but it does mean that other actors are enrolled to stabilise LCA and thus the Thiel article.

In the Saur article, we saw several impact categories. An overview of several impact chains covering some of these categories is shown in Figure 4-201.

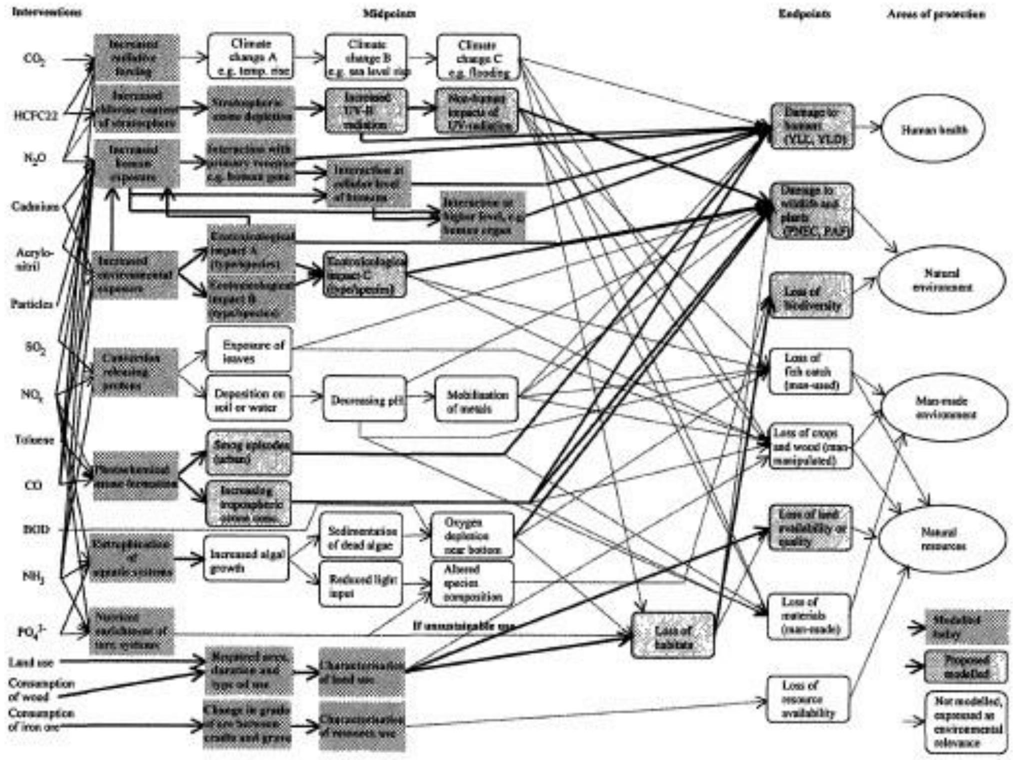

Fig. 4: Overview of the causal relationships between environmental interventions, midpoints and (category) endpoints

Figure 4-21 The route from emissions to endpoints for several substances (Udo de Haes et al 1999)

The diagram may be hard to read, but this merely serves to emphasise the complexity of the subject. At the far left, a list of possible environmental interventions (i.e. chemical components and other potentially harmful factors) is given. At the far right, different "Areas of protection" are exposed. These are 'Human health', 'Natural environment', 'Man-made environment' and 'Natural resources'. In between are the paths that the environmental interventions move along to create detrimental environmental impacts; referred to as midpoints and endpoints. The extent to which the lines cross each other shows how different emissions can lead to more than one impact and how more than one emission can lead to the same impact. When we also know that there may be interactions between the different endpoints, for instance the impact categories labelled "climate change" and "acidification", the picture becomes even more complex.

To understand the link between emissions of chemical substances, things we value and the impact categories, or what is referred to as an environmental mechanism in ISO 14042 (2000), the concept of an impact chain may help. Figure 4-22 shows such a chain for climate change.

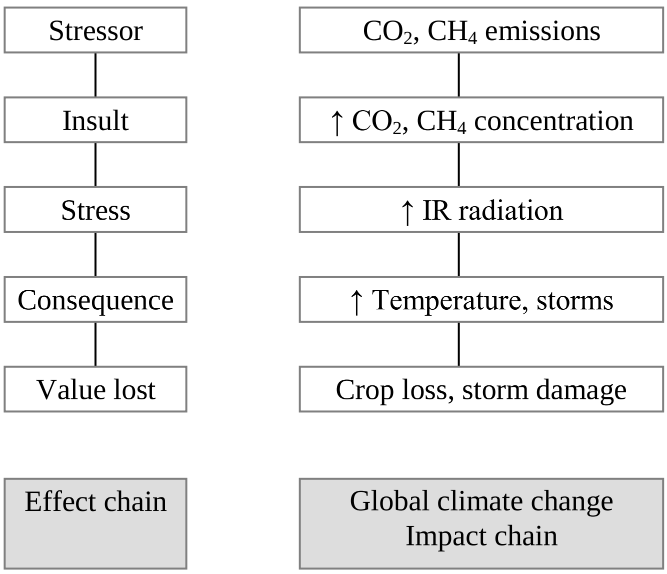

Figure 4-22 The effect and impact chain shown for global climate change (Hertwich & Pease 1999; Holdren 1980)

As we can see, the chain only gives a few examples of emissions that can create climate change (CO_2 and CH_4) and, similarly, only a few examples of unwanted outcomes (crop loss and storm damage). What is worth noticing,

however, is how LCA (and thus the Thiel article) captures environmental impacts somewhere between the emissions and the loss of value. The GWP is connected to IR radiation and is therefore placed in the middle of the chain as an environmental stress, while the value for the GWP is the total sum of the absorption of the different emissions related to climate change. When moving down the impact chain, relevance for human beings increases - but so too does scientific uncertainty. The measure is thus a compromise between capturing the "real" environment (i.e. the true causal relation between emissions and impacts) and something we care for. Now we are better equipped to understand a sentence in ISO 14042 stating: "The category indicator can be chosen anywhere along the environmental mechanism between the LCI results and the category endpoint(s)" (ISO 2000, p. 9).
In relation to climate change, and remembering that ISO 14042 explicitly refers to the IPCC model, here is what Heijungs et al (1992) have to say:

> "Rapid developments are still taking place in the area of the greenhouse effect. It is clear, therefore, that these will have to be closely followed and that GWPs should be modified in accordance with the latest developments. To avoid the need to change the GWPs after every publication in this area we propose that the GWP should only be revised further to new IPCC reports".

This statement effectively ties the method of LCA and the scientific development within IPCC together, thus confirming IPCC's status as an actor in the LCA actor-network for an undefined future.

The links between LCA and the environment have become clearer, but the assumption that there is widespread use of LCA has not been proven just because there was one other article (the Saur article) in addition to the Thiel article. Nor are the actors necessary for creating an LCA actor-network or the connections to bumper carriers (or any of their other names) or the automotive industry explored to any degree. The time has come to reveal the history and development of LCA. Fortunately, there are plenty of articles discussing these issues, as well as plenty of articles that make LCA visible within the automotive industry.

Although not all articles discussing the history of LCA agree on the exact starting point, they all trace the roots of LCA back to the 1960s. Some refer to Harold Smith as the inventor because of an energy calculation for the production of chemical intermediaries presented at the World Energy Conference in 1963 (Buchinger 1993; Tsilingiridis et al 2004). Others attribute the tool to Harry Teasley, who sponsored a comparison of different beverage containers in 1969 (Hunt & Franklin 1996). "The analysis was conducted by the Midwest Research Institute and the concept became known as REPA (Resource and Environmental Profile Analysis). It was the basis of the Life Cycle Inventory methodology development within the existing LCA idea (Hunt et al 1992)" (Lee et al 1995).

About 15 REPAs were conducted between 1970 and 1975. They "emphasized raw material demands, energy demands, and waste generation flows; attempts on more sophisticated analysis through environmental impact classification would come later in the evolution of LCA methodology" (Hunt & Franklin 1996)

Then there was silence.

This may be due to the fact that the US Environmental Protection Agency thought it impossible to carry out REPAs for every product, especially since their regulatory control was directed towards companies and sites, rather than products (Hunt & Franklin 1996). The LCA method, however, suddenly reappears more than a decade later. Fava (2005) writes:

> "In the late 1980s a number of "duelling" life cycle assessment studies attempted to illustrate the superiority of one product over another. As these studies gained visibility, issues associated with boundary conditions, sources of data, and functional unit were revealed. In response to these issues, as well as to concerns by industry, government, and the public about the proliferation of local and national environmental standards, ISO – the International Organization for Standardization, based in Geneva – established a technical committee (TC-207) to develop environmental management tools (including LCA) that would be applicable worldwide…[In] 1990, the Society of Environmental Toxicology and Chemistry (SETAC) sponsored an international workshop which resulted in "A Technical Framework for Life Cycle Assessments."…[SETAC] established the terminology and framework for LCA development worldwide. In North America and Europe, SETAC set up LCA advisory groups whose mission has remained to advance the science, practice, and application of LCA. SETAC has partnered with the United Nations Environmental Programme (UNEP) to establish the UNEP/SETAC Life Cycle Initiative to develop practical tools for evaluating products and services over their entire life cycle to achieve sustainable development" (p. 17)

Here, LCA is coupled with yet more organisations: SETAC and UNEP. The latter we have already met as one of the establishing organisations of IPCC. The former, SETAC, was established in 1979 because, according to the organisation itself (SETAC 2007):

> "In the 1970's, no forum existed for interdisciplinary communication among environmental scientists – biologists, chemists, toxicologists – and others interested in environmental issues such as managers and engineers."

Such a connection increases credibility and makes the road from science relating to various species and the specifics of problems in nature to LCA shorter.

During the 1990s, LCA gained momentum and several industries embraced the tool as a method for capturing environmental impacts. LCAs were also increasingly discussed in articles and reports within automotive research, although many were performed by car companies and not available to the public. There are at least three different approaches that connect LCA and cars, where 1) are those authors who combine LCA and automobiles to say something about both, 2) are those who use cars as cases in LCA and 3) are those studying other aspects of cars, but referring to the usability of LCA. Examples of the first are Gaines and Stodolsky (1997b) and Ha et al (1998), who simultaneously expand knowledge about LCA and knowledge about the environmental impact of different aspects of cars. An example of the second approach is Fitch and Cooper (2004), where a case from the automotive industry is used to expand LCA methodology. Finally, examples of the third approach are MacLean and Lave (2003), who discuss the use of LCA related to different fuel options, but also go through a range of studies performed; and Colvile et al (2001), who emphasise how LCA might be used to find out about atmospheric emissions from transportation.

The International Journal of Life Cycle Assessment was established in 1996 as yet another actor with the potential of increasing interest in and the credibility of LCA, but more importance should probably be attributed to the development of easy-to-use software tools (as for other aspects of the Environment*). Hunt and Franklin (1996) have provided a personal reflection on the difficulties of performing LCA (REPA, that is) in the early 1970s:

> "One of the interesting aspects of the early studies was performing the calculations without the aid of electronic computing equipment. The many hundreds of calculations were done on a mechanical calculator that did not even have a paper tape print-out. It consisted of electric motors and rotating wheels. Whenever an error was found and values had to be recalculated, it was a very time-consuming task. In 1973, the first LCA computer program was funded by an MRI client. The data filled several boxes containing many hundreds of punched cards. The information on the cards had to be loaded into the computer with a mechanical feeder any time we wanted to do calculations. Often the

> feeder would not read one or two cards correctly, and we had to start all over. The computer would often just tell us there was an error "somewhere", which meant we would have to hand sort through the boxes of cards and try to find the card error" (p. 5).

In the 1990s, numerous data tools were developed to keep track of inventories, to store databases for impact factors, to calculate the final category indicators and to present results in an attractive fashion. The ability of easy storage and retrieval of vast amount of data has increased the potential to actually perform analyses.

But how does LCA relate to the impact categories examined earlier - global warming, acidification and eutrophication? Comparing the impact potentials from the first round and the content of the categories specified in this round gives the impression that LCA is not up to date on the environmental problems. There are, however, vast discussions on how to capture category indicators in the LCA community and it may well be that the Thiel article could have chosen a different, more sophisticated approach by drawing on the LCA literature. In fact, even Heijungs et al. (1992) recognised that there were developments in modelling of issues such as acidification to make it more accurate and more site specific and these authors even explained why it was not employed:

> "It might be desirable to include an effect factor in classifications at a lower level of scale. Such an effect factor could be based on the *critical loads* for H* which have recently been developed (Hettelingh et al 1991)…[When] an effect factor is added the potential H+ equivalents have to be converted to more appropriate equivalents for a given area by using dispersal and deposition models (which should include degradation processes, etc.). These equivalents can then be compared with the critical load for the area concerned. Such models have been developed for Europe (Alcamo et al 1987) and should also be developed for other Continents. A future spatial differentiation of the acidification classification could be implemented in this way. However, the inclusion of an effect factor would not be useful for the generic classification at global level developed in this study. A global average critical load would not provide any differentiation" (p. 75).

Such articles that try to incorporate new findings in study on eutrophication (Finnveden & Potting 1999; Huijbregts & Seppala 2001) and combinations of acidification and eutrophication (Krewitt et al 2001; Seppala et al 2006) have increased in number after the publication of the Thiel article (although I am not claiming that they have increased as a consequence of the Thiel article). The actor-network shown in

Figure 4-12 is not just used by Thiel and Jensen, but is also the result of numerous scientists, articles and other actors striving to connect the entities together. Here we have met yet more articles on LCA, we have met other environmental impacts, impact chains, SETAC, UNEP (again), computers, the International Journal of LCA and other actors stabilising the Environment*.

4.2.2 The actor-network after the second round

The Environment* is all the more visible now. It has become inhabited by many different species, measuring technologies, scientific bodies, data models, journals, maps, numerous lakes, rivers, trees, data models and organisations.

LCA has made connections to a large number of environmental effects. However, we have also seen how LCA has disconnected itself from the endpoints when establishing indicators, hence the specifics of nature are not taken into account. The environment thus consists of an average soil, of average air and of average water to the extent that the environment consists of such entities at all. After all, the endpoints of concern (e.g. human health) have mostly been indicated. The scientific certainty is much higher for a casual relationship between emissions and their impact on some physical entity (e.g. increased absorbed IR radiation from increased CO_2 emissions) than for the relationship between such a change in nature and a value that we care for. The impact potentials are therefore hybrids – quasi-natural measures somewhere between the release of a substance and its impact on something that is valued. All chemical components bringing a similar effect are translated into one, thus making the whole lot manageable.

As a consequence, the environment described by researchers interested in specific environmental issues is much more detailed than the environment described in LCA. This does not, however, alter the fact that the more established and comprehensive impact categories can be described "outside" LCA, the more this stabilises the LCA concept. From all the articles in the International Journal of Life Cycle Assessment devoted to impact categories and which models to use, it can be deduced that there is a desire to ensure the specifics are included.

Although articles and standards stress that LCA can be used to improve environmental aspects of products at various points in their life cycle or to enhance decision-making, the method is also defining what the environment is. If it is not a part of LCA, it probably has no negative impacts on the environment. Thus, LCA provides a means of both confirming what the environment is and enhancing the image of the environment as a vulnerable sphere in need of protection from (and also for) human activities.

Figure 4-23 shows the Environment* actor-network after the second round. Not all the actors mentioned in the second round are included, but the diagram indicates several new actors that have joined the actor-network.

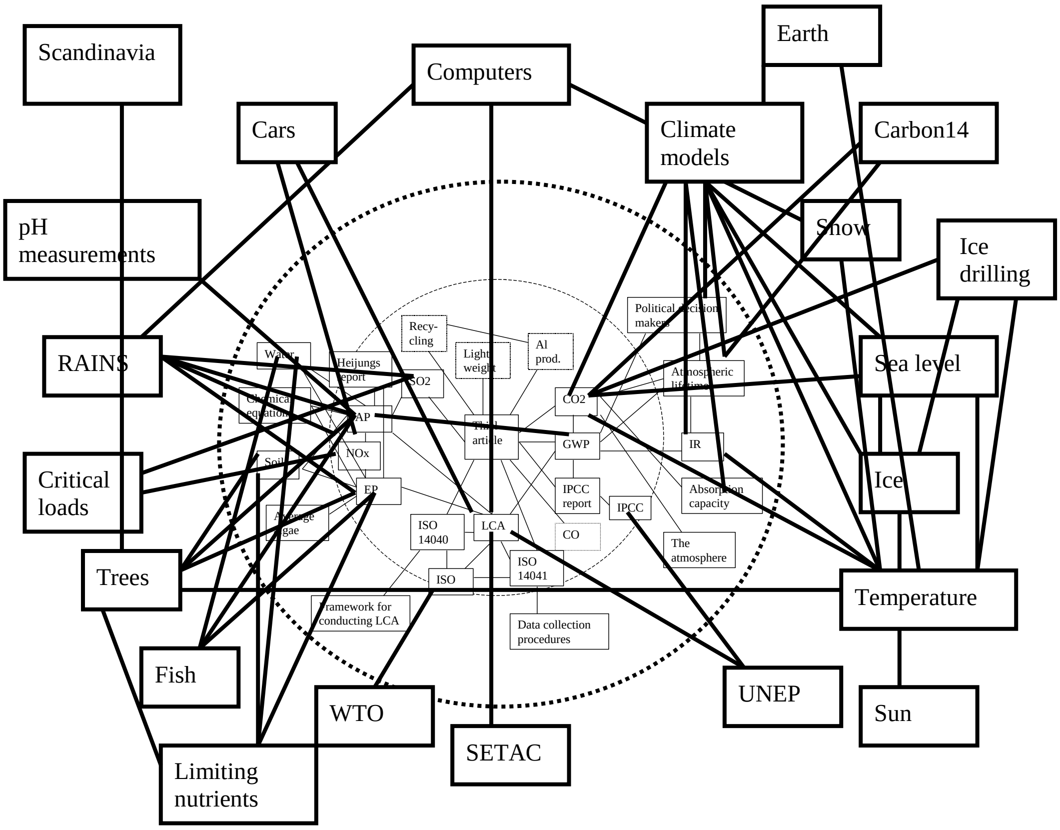

Figure 4-23 The Environment actor-network after the second round*

The three impact categories we have followed most intensely seem to have been well established during the 1980s. They are connected to research stretching far back in time, as some examples show, but the stability of the actor-networks was not achieved before enough elements to keep them in place were present. Even if some elements such as the basic technologies (e.g. equipment for temperature or pH measurement) were black boxed long ago, the definitions of the environmental problems had to wait until enough stability granted them reality.[110]

It soon became apparent that it is impossible to follow all the links, all the small details that have been translated, emphasised, forgotten, black-boxed and otherwise transformed into what constitutes the Environment*. As the three impact categories that were the focus of the Thiel article vanish as we move backwards to the beginning of the 1980s, we must search elsewhere to find out what the Environment* was like in the 1970s. Remember that we want a description of the Environment* in the entire period from 1970 to 2006.

The boxes with dotted lines from Figure 4-12 in the summary of the first round are still dotted after the second round (although it is almost impossible to see). Thus, there are still actors holding the Thiel article together that we have not touched upon and these may shed light on what the Environment* was like in the 1970s.

4.3 Resources and local pollution: connecting to the 1970s

The Environment* captured in the Thiel article (2000) is built on elements that fade out at different points in time as we move backwards and follow the actors in the actor-network. Few of them have any momentum or stable connections, when we reach the end of the 1970s. Although all three impact categories in the article have connections to even earlier research, there are other environmental issues that were more pressing in the 1970s. As we will see, some of them are closely connected to other as-yet unexamined concepts introduced in the Thiel article.

4.3.1 Third round: other environmental issues before the Thiel article – reconnecting to the bumpers

Have we lost sight of the bumper? The second round gave us a better picture of the environmental issues connected to the Thiel article, or the Environment* as denoted here. However, whilst describing the materials used for stabilising global warming, acidification and eutrophication, we did not meet any bumpers or bumper beams. Even references to emissions from automobiles have been few. Aluminium has made its presence felt, but as a negative contribution to acidification, not as industrially produced

[110] Although different temperature scales such as Celsius, Fahrenheit and Kelvin can still cause problems to most people who encounter a temperature reading in a scale they are unfamiliar with.

aluminium for economical use. It is not strange that the bumper disappeared from view. The environmental issues of the 1980s were connected to pollution sources other than cars and aluminium, such as coal-fired power plants, nuclear power plants and refrigerants. In this round, it is time to reconnect to bumpers, to find the bumpers and the aluminium again and to trace the Environment* from there. In other words, to see how the environmental actor-network coupled to aluminium bumpers has been created and developed.

Lightweight cars and fuel consumption

The Thiel article referred explicitly to the connections between weight, fuel use and emissions. As such, the Thiel article is one of a number of articles between 1990 and 2000 that looked at weight savings and better fuel economy from the application of aluminium in cars (Kirchain et al 2000; Martchek et al 2000; Peterson 2000; Schukert et al 1995; Stodolsky et al 1995). The conclusions are largely the same for most of the articles and can be summarised in the words of Allen et al (1994):

> "The automobile industry has made significant progress in recent years in reducing fuel consumption and emissions while striving to provide the high level of performance, safety and comfort that consumers demand. Light weighting has been used increasingly as a means of reducing fuel consumption and emissions" (p. 3).

Many of the articles were connected to research projects on reducing the weight of cars, with the Partnership of a New Generation of Vehicles (PNGV) being one of the largest. Hadley et al (2000) wrote:

> "[With] higher efficiencies and lower emissions among the goals of the automotive industry and federal government, programs have been established to conduct research on using more aluminium in vehicles. The Partnership for a New Generation of Vehicles (PNGV) provides the opportunity for manufacturers and the government to conduct joint research projects in creating aluminium-intensive vehicles that can achieve three times the mileage of current models" (p. 1).

With the increase in the use of aluminium in cars as an explicit goal, articles spanning from infrastructure for increased production to technical characteristics of cars were published.[111] Enhanced fuel efficiency is partly

[111] Gaines and Cuenca (2002) write: "The Al body stood up well and had no rust, rattles, or failures. It was unfortunate in a way that the vehicle was not involved in any significant accidents, so no information was obtained on either repairability or behaviour of the vehicle's body under stressed conditions." Only in a research report can car accidents *not* happening be unfortunate.

argued for as a means of avoiding dependency on fuel imports in the USA, but many also make the connection to environmental issues. Miller et al (2000) argue for more use of aluminium in the automotive industry "triggered by concerns about global warming and energy usage." They provide usage statistics that are positive for all proponents of aluminium, as shown in Figure 4-24.

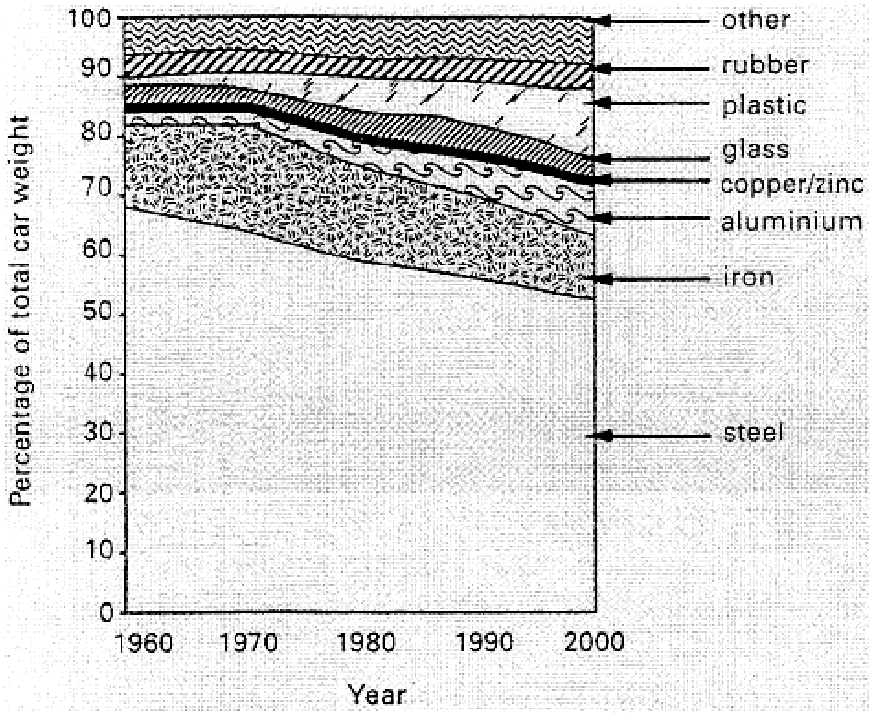

Figure 4-24 The change in material consumption in the average car (Miller et al 2000).

The diagram shows that there has been a gradual decrease in the relative use of steel in automobiles, whilst aluminium use begins to increase in the early 1970s. Knowing that the average weight of a car has been increasing at the same time, this means that the absolute amount of aluminium used in an average car has increased further. The increase in aluminium use was partly connected to the issues of lightweight cars and fuel efficiency that really started to make their presence felt in the 1970s and also started to show up in articles. A number of articles were published on the advantages of using aluminium in automotive applications. However, the rationale for focusing on fuel efficiency was not exactly the same as twenty years later. None of the articles from the 1970s explicitly focus on the word environment, but links are made to fuel efficiency and resource conservation

George et al (1976) write:

> "There are many factors that affect fuel economy such as vehicle size, weight, engine size, emission controls, aerodynamic shape, and accessories used. An improvement in fuel economy is possible by varying any or all of the above factors. An important factor in fuel economy is vehicle weight because it interacts with other aspects of the automobile such as road performance, emissions, and structural requirements. Since decreasing weight has become more important, interest in aluminium applications in automotive design is rising."

They continue:

> "The use of aluminium in automobiles can represent significant weight reduction. On an equal volume basis aluminium weighs 1/3 as much as steel. There are instances where aluminium has other technical advantages, but by far its main advantage is its weight reduction potential and its influence on fuel economy. …[When] automotive engineers are looking for a weight reduction, one of the first places examined is the bumper system. This is because bumpers are a relatively heavy structure having a well defined technical function (determined by federal regulation)"

Thus we learn that the aluminium bumpers are in fact special, as they are especially viable for weight reductions. The article even provides links to the political and legal systems. Another good example is Hatch (1977) who argues:

> "Emphasis put on vehicle weight reduction by the automobile industry to increase fuel efficiency is one of the reasons for aluminum's growth in bumper system applications. Aluminum's high strength to weight ratio makes it a candidate material for bumper systems that must comply with FMVSS 215, part 581."

Hatch specifies the reason why aluminium is especially viable for weight reductions and also the specific element in the legal system to which the bumpers are connected. In his conclusions, he relates the weight savings to the environment:

> "In the selection of materials and systems, one must consider not only cost-effectiveness of a particular design, but the effect on conserving our natural resources."

Here, "conserving our natural resources" is providing a connection to the Environment*. The most observant readers may remember that "Resource Use" measured in scarcity units was one of the impact categories included by Saur et al (2000) in their study of aluminium fenders. Starting to use a new material (or rather an old material for new applications) also required testing of its behaviour under real conditions:

> "New alloys of aluminium have been developed, together with thermal treatments and fabrication techniques, to meet special requirements in the automotive field. While the corrosion behaviour of these materials can generally be anticipated from a knowledge of the corrosion characteristics of related alloys, new and extensive testing is needed to verity their performances. Therefore, in 1974 we planned a comprehensive atmospheric exposure test program. Consultation with a major automobile manufacturer confirmed the desirability for field testing in three important areas: (1) conventional plated steel bumpers versus aluminium bumpers having several finishes (bare alloy, anodized coating, organic coated, and chrome plated metal)…[The] article shows that empirical testing of bumpers and bumper materials are needed to gain insights that cannot be deduced from theory. (Ailor Jr. & Wilkinson 1977)

The citation hints at the trials aluminium must undergo in the hands of scientists to be translated into a material good enough for the automotive industry. However, trials and testing were not confined to aluminium only. Weight reduction also became a threat to steel producers, who responded by developing new types of steel using the same argument of the need for weight reduction (Kary 1976).

Resource scarcity

In the early 1970s, the view that the world would run out of resources was widespread in research. The report "Limit to Growth" and the article "A Blueprint for Survival" were leading a debate, which was also heavily influenced by the 1973 oil embargo and the first picture ever of the whole Earth from the Apollo 17 space shuttle.[112] These different contributions were involved in the establishment of institutions such as the World Resources Institute (WRI) and US legislation such as the 1974 National Commission on Supplies and Shortages Act.

The idea that resources might run out was not a novel idea. Not in practice, where human settlements have always been dependent on securing a supply

[112] The picture is often stated to be the most widely published picture in the world – it made the definite limits of the Earth and the vastness of space visible. (Maher, 2004)

base, and not in theory, where the infamous work by Malthus must be considered to be one of the earlier contributions.

Since "Limits to Growth" was instrumental in setting up the debate in the 1970s, a whole range of issues connected to the usability of dynamic modelling, parameters for equations and economic assumptions were brought to the table. Unlike the environmental issues we have encountered so far in this chapter (i.e. the "newer" environmental problems), economists became widely involved early on with defining resource depletion (almost to the point of defining it away). Natural scientists seemed furious about economists' participation in the debate, or at least their writings show signs of this, here in the words of Georgescu-Roegen (1975):

> "The favourite thesis of standard and Marxist economists alike, however, is that the power of technology is without limits (Barnett & Morse 1963; Beckerman 1972; Bray 1972; Johnson 1973; Kaysen 1972; Report on Limits to Growth 1972; Solow 1973). We will always be able not only to find a substitute for a resource which has become scarce, but also to increase the productivity of any kind of energy and material. Should we run out of some resources, we will always think up something, just as we have continuously done since the time of Pericles (Beckerman 1972). Nothing, therefore could ever stand in way the way of an increasingly happier existence of the human species. One can hardly think of a more blunt form of linear thinking."

He continues in the same fashion:

> "In Solow's hands, substitution becomes the key factor that supports technological progress even as resources become increasingly scarce. There will be, first, a substitution within the spectrum of consumer goods. With prices reacting to increasing scarcity, consumers will buy "fewer resource-intensive goods and more of other things" (Solow 1973). More recently, he extended the same idea to production, too. We may, he argues, substitute "other factors for natural resources" (Solow 1974). One must have very erroneous view of the economic process as a whole not to see that there are no other material factors than natural resources. To maintain further that "the world can, in effect, get along without natural resources" is to ignore the difference between the actual world and the Garden of Eden"

The citations not only show his contempt for the view of economists, they also expose his underlying belief in the world as a closed system. A belief earlier explicated by Boulding (1966), where he shows what the image of a closed system has to wrestle with:

> "We are now in the middle of a long process of transition in the nature of the image which man has of himself and his environment. Primitive men, and to a large extent also men of the early civilizations, imagined themselves to be living on a virtually illimitable plane. There was almost always somewhere beyond the known limits of human habitation, and over a very large part of the time that man has been on earth, there has been something like a frontier. That is, there was always some place else to go when things got too difficult, either by reason of the deterioration of the natural environment or a deterioration of the social structure in places where people happened to live. The image of the frontier is probably one of the oldest images of mankind, and it is not surprising that we find it hard to get rid of."

Boulding also refutes the view of economists and describes them as especially sluggish in realising what the earth really is.

> "Economists in particular, for the most part, have failed to come to grips with the ultimate consequences of the transition from the open to the closed earth".

Another natural scientist, Cook (1976), does not employ such general insults; rather he couples the insights from geology with those from an economic perspective:

> "Despite the fact that strongly positive geochemical anomalies are relatively small and rare and appear to be restricted to the outermost part of continental crusts, the history of economic exploitation of non-renewable resources over the past 200 years is, in general, one of decreasing and increasing reserves. However, the direct energy or work costs of recovery have been rising, slowly for a long while, then more rapidly as the number of tons of ore required to produce a ton of refined metal has started to rise more steeply with decreasing ore grade…Now that energy resources themselves are beginning to cost more in work, now that the efficiencies of energy conversion appear to be nearing limits dictated by the strength of materials and the laws of thermodynamics, and now that the work costs of recovery, at least for some resources, are moving up the steeper parts of exponential curves, the nature of the limits to exploitation of non-renewable resources is beginning to be recognized".

Despite these examples of instructive texts by natural scientist, the economists and the world at large were never really convinced. When Simon (1980) broke the false myths about the present bad state of the world, about population and resources, it was almost too late. The false myths had already been brushed aside as myths by both researchers and the wider audience. That the concern for resource conservation diminished rather than grew stronger was connected to both updated estimations of the resource base and an increase in concerns over other environmental issues. According to Ausubel et al. (1995):

> "While energy use [since 1970] has increased, so have estimates of the energy available, in the form of resources that might eventually be tapped. Contrary to expectations that the world would begin to exhaust its supply of so-called fossil fuels, proven reserves of oil have increased from 600 billion barrels in 1970 to 1,000 billion today, even though over 500 billion barrels have been pumped from the ground in that time. Proven reserves of natural gas have tripled over the last twenty-five years."

These authors even go so far as to state that:

> "The possibility that environmental concerns such as the build-up of atmospheric greenhouse gases would diminish because of the depletion of exhaustible resources has thus become more remote."

They are thus asserting a claim as to why climate change has increased in importance as an issue, a claim that is also found in a work by Randers (2000).[113]

> "[A lesson] from history since 1970 relates to parameterisation. It now appears that the tightest constraint on physical growth is not resource scarcity, or vulgar shortage of raw materials. Rather the most pressing limit seems to be on the emissions side. To be concrete, the world appears to have much more fossil fuel than was assumed, indeed more than man can burn without causing serious climate change.
>
> This is of course, in our language, nothing but a question of parameterisation. No serious system dynamicist would insist on the validity of the individual parameters chosen for the early models World2 and World3. For us the main message is the overshoot and decline mode, which resides in the basic structure of global economic and population growth. For us it does not matter what triggers this mode. For us, what matters is that growth in face of limits, and governed by delayed decisions, will produce overshoot" (p. 215)

However, returning to the LCA guide by Heijungs (1992), we find that resource depletion was still an issue in the early 1990s:

> "The depletion of resources is at the heart of the discussion about sustainability and is a problem in its own right. Depletion may lead to a

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[113] Randers was also one of the authors of "Limits to Growth".

> loss of functions and potential functions of certain material applications. Furthermore the continued use of resources may lead to a shift to poorer or less favourably sited reserves thus resulting in greater emissions, damage, desiccation, etc. For these reasons it is useful to include the aspect of depletion in the classification of an LCA."

Although resource scarcity on a global scale was largely refuted at the beginning of the 1980s, institutions and tools connected to the idea have still remained.

Production and recycling of aluminium

Two other boxes with dotted lines in Figure 4-12 represent the production of aluminium as an actor, and recycling. For aluminium to be part of the idea of a more environmentally friendly bumper carrier, its production cannot have too severe an environmental impact. However, the production of aluminium has a history of a poor environmental reputation. Asdal (2004) writes that:

> "[The aluminium production sites] Årdal and Sunndal were after a while just as renowned for the detrimental effects from the production of aluminium as the aluminium production itself. Aluminium changed character. The product could no longer be separated from the effects it created."

Since then, aluminium has gone through a transformation due to decreases in the emissions of pollutants and a focus on recyclability:

> "As worldwide concerns about the Environment increase, the ability to recycle automotive components and materials is becoming an important consideration in the design of a vehicle. The amount of energy required to remelt aluminium scrap is only 5% of that needed to produce molten metal from ore [1 = Recyclability and Design 1992 Automotive Design and Fabrication Seminar, Detroit, MI, November 4, 1992]. From an Environmental perspective, it clearly pays to maximize the reuse of aluminium components whenever possible. The economic and technological enablers to recycle exist. Therefore, when a component is designed with aluminium, the entire cycle of material from use through reuse is put in motion" (Allen et al 1994)

Gaines and Stodolsky (1997a) criticise studies which claim that "use of lightweight materials results in only minimal lifetime energy savings, and therefore should not be given high priority". They argue that:

> "[These] studies make several errors. The first error is failing to recognize that, even if lifecycle energy use is not reduced by substitution of lightweight materials, dependence on petroleum is

> definitely reduced, and this may be a key cost and national security concern (imprecise criterion definition). The second error is simply neglecting the secondary weight savings enabled by using lighter components. Secondary weight savings accrue as a result of redesigning other components to take advantage of the lighter vehicle body. These savings reduce production energy and further reduce gasoline consumption (technical detail not covered in standard methodology). Correction of this error results in reduction of break-even mileage. The third error is the use of virgin aluminium in the energy calculation (incomplete set of systems analyzed). Some of the aluminium currently used in cars is cast and some is wrought (sheet and extrusions). The cast aluminium is already largely recycled, but the wrought aluminium is generally virgin, because all the aluminium currently recovered from cars goes into cast products. No credit is given for energy recovered from recycling the recovered wrought products to cast products (or in some cases, even from recovered cast products) in the faulty studies, and no thought is given to the obvious solution. In the future, if large quantities of wrought aluminium are used in cars, the material will be recycled, drastically reducing the energy requirements for aluminium auto parts."

How could anyone speak against aluminium? If one were to take all of the positive effects mentioned above into account, it must be environmentally friendly. Not just that, there is even work going on to make it even more environmentally friendly:

> "Development of advanced anodes and cathodes and processing and recycling of aluminium wastes are some of the areas that currently are being funded to reduce energy consumption, pollution, and production costs of aluminium." (Hadley et al 2000:17)

You may be puzzled that there is little mention of the detrimental effects of fluoride emissions from aluminium smelters in the text - and so am I. The Norwegian aluminium industry was haunted for years by the effects on vegetation and animals around the major aluminium production sites. These effects led to controversies, to scientific publications and even to the establishment of Røykskaderådet – the predecessor to SFT (the Norwegian pollution agency). However, the controversies were as good as settled by the 1970s. Most articles connected to the emissions and impacts had been published and already forgotten (e.g. Bohne 1970; Braanaas 1970; Danielsen 1960; Nestaas 1970) and only a few exceptions were published later (e.g. Arnesen et al 1995; Horntvedt 1995; Thrane 1987).

Local air pollution

For those of you with a superhuman memory, carbon monoxide (CO) was the last actor in Figure 4-12 that remains to be explained. Actually, so far we have seen very few connections to CO until it suddenly shows up here, in an attempt to "finish" the actor-network I started to capture. I must, however, disappoint you (and me as well). Carbon monoxide is just not a subject of major interest. There are references to carbon monoxide in health journals and writers in environmental sciences seem to agree that CO emissions are bad for you, but I have not managed to come across any substantial writings on CO since 1970. Perhaps I should have searched more diligently or earlier, perhaps it suffices to say that carbon monoxide and other local pollutants with direct effects on plants, animals and humans were already well established, black-boxed and unnecessary to speak of after 1970. However, this is contrary to the views of Selin and Eckley (2003):

> "The first public warnings about possible dangers came in relation to local environmental effects in the early 1960s, and grew stronger in the 1970s (Anonymous 1966; Carson 1962; Jensen 1972). As such, the chemicals problem was first seen as a local problem" (p. 22)

This does not contradict the idea of first seeing environmental problems as local problems. The claim that public warnings grew stronger in the 1970s does not have to be related to a strong *scientific* focus in the same period. Hints that this may be the case are provided by Colvile et al (2001):

> "Ellison and Waller (1978) reviewed the evidence on the health effects of urban air pollution (principally sulphur dioxide and suspended particles), with particular reference to the UK. They concluded that urban air pollution until around 1968 caused increased mortality and morbidity, with exacerbation of pre-existing chronic respiratory disease, but felt these effects were not longer occurring. The sooty smogs of the 1950s had also been highly visible and tangible, so the improvement in air quality could be seen, smelt and even tasted by the general public as well as monitored by scientists, adding to the general impression that the problem had been solved." (p. 1542).

As surprising as the small number of articles related to cars and the environment in the 1980s is the lack of articles on local air pollution in the 1970s.

4.3.2 The actor-network after the third round

The third round was even messier than the two previous rounds. There has been a larger movement in time and issues jumping from the 1970s to the

1990s and back again, from a focus on one environmental issue to another. The red thread is missing.

It becomes evident why the Thiel article could not have been written 20 or 30 years earlier. The focus was elsewhere. Data had not been gathered. The Environment* had yet to be effectively translated into graphs and numbers. EPA had turned down the idea of assessing all products. Hence, the alignment of all the elements – databases, simple equations for complex environmental relationships, shifts from a production to a product focus – made LCA and the Thiel article possible.

Connections from the issues high on the agenda in the 1970s are still present in the year 2000, even for actors that were refuted and discarded, such as resource scarcity. The connections are, however, more difficult to trace, as is the degree to which they provide stability to the Environment* (i.e. the actor-network consisting of environmental issues related to bumpers)

4.4 Fuzzy boundaries of the Environment*: 2000-2006

The concepts from the Thiel article have been examined and I have presented the content and the way the concepts have been stabilised. However, the time period from 2000 to 2006 has not yet been covered and needs attention, in order to create a parallel description of the Economy* and the Environment* and thus provide the symmetry necessary for comparing the descriptions.[114]

If the third round was messy and confusing, the fourth round will probably be much riskier. I am moving away from my fixed point, the Thiel article, and into open spaces to capture historic processes of an extremely temporary nature.

4.4.1 Fourth round: environmental issues after the Thiel article

It is difficult to predict what will be deemed the most important environmental issues between 2000 and 2006. Only history will decide which articles and directions continue and which are forgotten. There are, however, some issues that are begging for attention and that certainly can be treated here. Ideally, I should probably have treated those articles that refer to the Thiel article to investigate where the article "spreads", but the publications in the SAE database are both difficult to access and mostly

[114] For the same reason, pictures of the scientific actor-network in 1970, 1985 and 2006 are provided in the summary of this chapter.

attract researchers with special interests. Thus, given that the spread is hampered and the material limited, I have elevated myself to the position of choosing which issues to include and perhaps more importantly which to exclude. The elements presented here are therefore those that any scientists involved in the environmental characteristics of aluminium bumper beams would be interested in between 2000 and 2006.

Industrial ecology and sustainable development

Although the concepts of industrial ecology (IE) and sustainable development (SD) were introduced prior to the Thiel article, they have further grown and stabilised in the years after the turn of the millennium.[115] According to Randers (2000), sustainable development is one of the biggest concepts to have arisen in recent years. Commenting on progress since he contributed to "Limits to Growth", he observes:

> "But is there nothing new [since "Limits to Growth"]? Luckily there is… [There] is the new name: "sustainable development". It took some time to find, but in 1986 the Brundtland commission (World Commission on Environment and Development 1987) succeeded in coining a phrase that made Jay's "equilibrium" into 'sustainable development'. There was no change in the concept, but the new label was much more acceptable from a political point of view. It could be supported by the world's poor. Unfortunately, the new label was also much more confusing. It took nearly ten years for global society to remove some of the fog and concretise sustainable development into its three elements: financial sustainability, environmental sustainability, and social sustainability" (p. 215).

So SD is both politically acceptable and connects to both economical and social issues. There is a natural connection between LCA, IE and SD. As Eik (2005)notes:

> "According to Lifseth (1997), IE can be seen as the operational part of sustainable development, which is defined to be a "development which meets the needs of the present generations without compromising future generations to meet their own needs." (WCED). However, where sustainable development is concerned questions related to environmental, societal and economical issues in a global perspective, the concept of IE seems to be restricted to understanding and improvement of environmental and economical issues in industrial societies" (Eik 2005, p. 20)

[115] Which may explain why they were not part of the Thiel article or its immediate references.

LCA is again seen as a tool to accomplish industrial ecology (Ehrenfeld 2003), where IE means to create an industry that mimics nature and introduces the concept of "industrial metabolism" (Graedel & Allenby 1995). By using nature as a metaphor, the hope is to achieve what nature does (i.e. getting rid of all waste) in an industrial setting.

What makes these two concepts interesting with regard to the Environment*? First of all, the focus is broadened. The Environment* comes closer to the economic and social issues, as they are all placed under the umbrella of sustainable development. We are also introduced to something like a metaphysical hierarchy. Sustainable development is placed on top as the ultimate goal to be achieved. Industrial ecology is introduced as the mind set, or paradigm, to achieve the goal (Ehrenfeld 1997). Life cycle assessment is on the lowest level as a practical tool to be used within industrial ecology. SD and IE thus introduce an element that has not been explicitly present earlier, namely an overriding framework for environmental issues - almost like a new ontology.

Safety as environment

As a follow up of sustainable development connecting the Environment* to social and economical issues, the scope of environmental issues has increased. In the updated guide from the University of Leiden (Guinée et al 2001), casualties (i.e. damages to human health from accidents) are proposed as a new impact category. There are also working groups trying to establish work hazards as a separate impact category within LCA. This conforms to how sustainable development (and all UN-initiated environmental work since the conference in Stockholm in 1972) has made the boundaries between social factors and environmental factors more blurred.

The connections between environmental issues and human health have, in fact, made the environment as a category less obvious. It is no longer limited to encompassing resource restrictions or polluting substances, but can also include actors previously viewed as social. A potentially positive consequence is that some human activities may actually be environmentally friendly, instead of all activities bearing an environmental burden. An example from Colville et al (2001) illustrates this:

> "Even in the absence of tighter air quality standards, there are arguments for environmental improvement by road traffic reduction. This is in recognition that the effects of air pollution emissions from road transport are far from being the largest road transport related impacts on population health. In addition to road injury risk, large but very poorly quantified health benefits of road traffic reduction include

> increased physical exercise associated with most modes of transport other than the private car" (p. 1557).

It should not come as a surprise that Health* and Environment* are joining forces. [116] After all, we have seen that the Environment* is connected to what humans hold sacred and there is probably nothing as sacred to an individual as the individual's physical health.

Climate change – no room for others?

Although the Environment* has increased in width by encompassing still newer impacts and by renewing old issues through more sophisticated measurement techniques and technologies, there is also a trend towards 'reducing' the Environment* to only one impact, namely that of climate change.

During the late 1990s and the beginning of the new millennium, climate change started to overshadow all other potential environmental hazards. Although the idea that carbon dioxide emissions could affect the World's climate was introduced more than a century earlier, it took decades of work within various disciplines and increasing emissions from anthropogenic sources to establish climate change as a category for a broader range of research fields.

According to MacLean and Lave (2003): "As recently as a decade ago, climate change was a relatively obscure concept. It is now a key environmental policy issue." Reasons for the previous obscurity are given by Colvile et al. (2001):

> "Emissions of greenhouse gases came under global control somewhat less rapidly [than acidifying and/or ozone depleting substances] as a result of genuine scientific uncertainty concerning the magnitude of the problem combined with powerful lobbying by the fossil fuel industry."

Part of the reason for this transformation into a "key environmental policy issue" can be found in the temperature graphs for the time period between 1990 and 2006. Another factor is the vast research effort invested in the subject. Remarkable weather patterns and new world records for mean annual global temperatures have concerned the public as well as scientists.

[116] Health* is equivalent to Environment* and Economy*, that is the issues related to the domain labelled Health connected to bumpers and bumper beams. If this domain had been included from the start, there would have been a greater focus on damage and injuries from crashes, and also the links to bumpers as a safety feature of cars.

Not only are the models for climate change being refined, significant resources have also been put into investigating the potential effects of climate change. Scenarios with rising sea levels, deaths caused directly by heat or indirectly by draughts or diseases, flooding and storms are being calculated with high confidence levels (Weart 2007).

The wording of the researchers within IPCC has gradually become stronger, from stating that there is a possible connection between man-made emissions and a change in climate to stating a certainty about the connection. Research institutions have changed their scope as a result. For instance, the Centre for International Climate and Environmental Research (CICERO) at the University of Oslo has changed its focus from measures to avoid climate change into measures aimed at coping with climate change.[117]

This increase in focus on climate change has also been shown in "bumper science". Instead of taking up a number of potential environmental impacts, both Yamaguchi et al (2005) and Suzuki (2006) use LCA - but focus entirely on CO_2.

4.4.2 The actor-network after the fourth round

The Environment* between 2000 and 2006 has been subject to both increased hybridisation and increased specialisation. Hybridisation has occurred as a consequence of a broadening of scope, as demonstrated by the concept of 'sustainable development' and in the link with the health domain. Specialisation has occurred as a consequence of the increased focus on climate change. Climate change has almost managed to establish itself as the only relevant environmental impact category. These two movements are partly conflicting and yet they also feed off each other.

This short description of the altering of elements between 2000 and 2006 has not tried to explain what happened to all those actors present in the Thiel article. Instead, the intention has been to show the development of some of the more important actors. Thus, several of the elements included in the Thiel article not covered in this section are still part of the Environment* A picture of the actor-network constituting the scientific production of environmental issues with regard to bumpers (i.e. the Environment*) is provided in the summary to be presented next.

[117] Interview with Pål Prestrud

4.5 Summary and timeline

Much has happened between the "resource scarcity" of 1970 and the "climate change" of 2006. Journals and books where environmental issues are displayed have been produced in increasing numbers. These texts contain numerous figures, graphs and equations that are representations of how it is anticipated that the environment will respond to different human interventions, e.g. the emission of chemical compounds. Such representations relate physical entities 'out there' to ways of understanding them through a text so that, for instance, carbon dioxide is characterised by a certain lifetime in the atmosphere or a certain potential to absorb infrared radiation and warm the earth. These mechanisms – assemblies of texts and the material world they hint at – are used to define environmental problems. We have seen several examples of such assemblies in this chapter and the following section summarises the actors (i.e. the elements) that the Environment* has consisted of in the studied time period.

In order to provide symmetry between the descriptions of the Economy* and the Environment*, the scientific production network (i.e. the Environment*) in 1970, 1985 and 2006 is illustrated in the text where appropriate.

4.5.1 Summary of actors

Let us first see what the Environment* looked like in 1970. This is displayed in Figure 4-25.

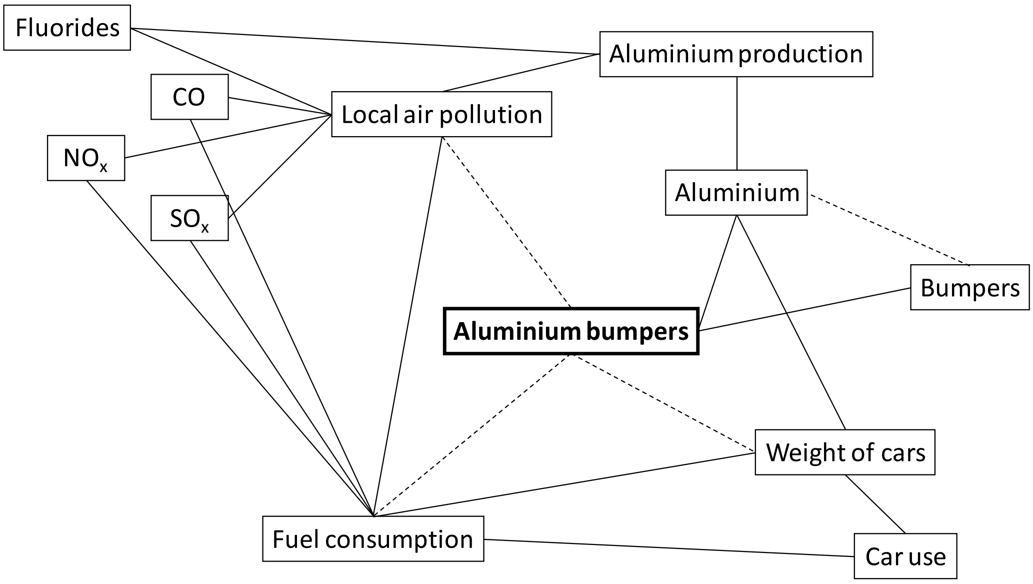

Figure 4-25 The possible Environment in 1970*

Many of the elements of the Environment* are displayed in Figure 4-25. Environmental problems existed in the form of local air pollution, consisting of emissions of fluorides, CO, NO_x and SO_x. The first of these chemical compounds was connected to aluminium production, while the three others were linked to fuel consumption and therefore car use. Articles existed that displayed relations between the weight of cars, fuel consumption and the use of aluminium, but no links existed between aluminium and bumpers in scientific texts.

In fact, the diagram shows that there was no Environment* in 1970. Bumpers were only loosely coupled to aluminium and no scientific articles had constructed the link between environmental problems and bumpers. Thus, what is displayed is a potential actor-network that would exist if anyone had asked for the bumpers' environmental characteristics.

The Environment probably came into existence in 1976 – or at least that is the year when the first article bringing bumpers, aluminium and the environment together is found. A focus on resource scarcity was established by the report "Limits to Growth" and the article "A Blueprint for Survival". Thereafter, the relative low weight of aluminium bumpers were praised in several articles for decreasing fuel consumption and saving natural resources. These texts also referenced the connection between aluminium bumpers and reducing local emissions of pollutants. Such local emissions were not an important part of science production in the 1970s, but were already black-boxed versions created in earlier decades. When the actor-network holding resource scarcity together dissolved at the end of the 1970s / beginning of the 1980s, articles praising the environmental importance of aluminium bumpers disappeared as well.

At the end of the 1970s and the beginning of the 1980s, other environmental impact categories were starting to make their presence felt. Research projects connected to acidification and eutrophication were undertaken. Computer models were central elements in several of them. These research projects were, however, mostly interested in the effects on nature caused by emissions, particularly NO_x and SO_x. The focus was on the death of fish and the death of forests, with connections rarely being made to sources of pollution. The few articles that established links between sources and impacts pointed more towards emissions from energy generation based on brown coal than the use of cars.

As we have now reached the mid-1980s, it is time to take a look at a picture of the Environment* in 1985. This is shown in Figure 4-26.

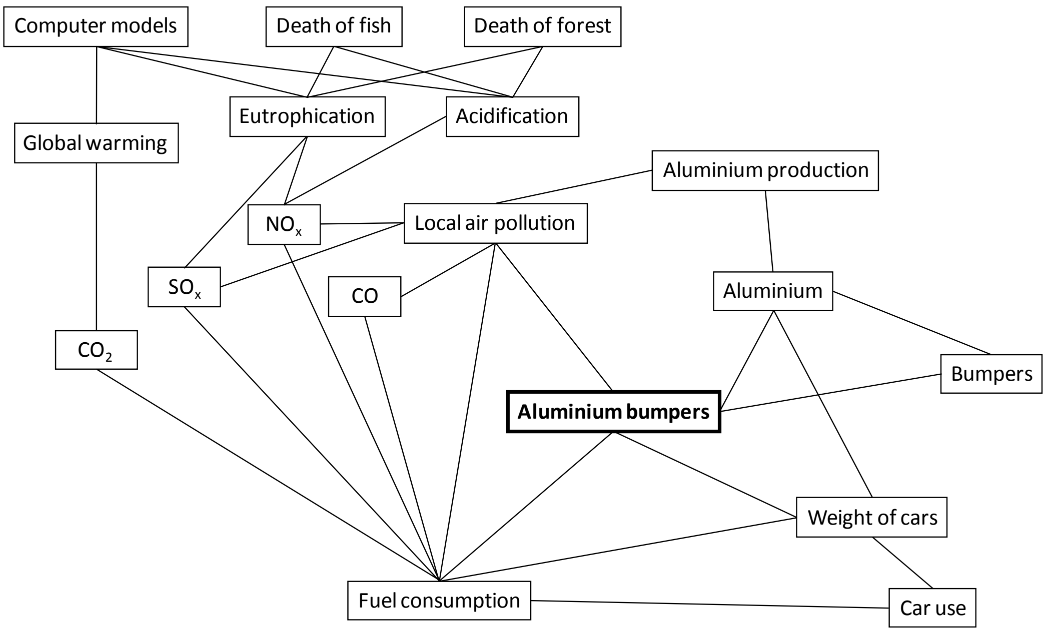

Figure 4-26 The Environment in 1985*

Figure 4-26 mainly shows the actors already presented in the above paragraphs, but visualises where the connections were present. In order to keep the Environment* stable, the connections were neither strong nor many. Thus, although it is possible to draw a picture of the network in 1985, the mid-1980s almost failed to contain the Environment* at all. The environmental issues in focus were found elsewhere, mostly connected to polluting electricity-generating sources (coal and nuclear power) or to refrigerants (CFCs). Nevertheless, important work was carried out in relation to impact categories that really made their presence felt during the end of the 1980s and the beginning of the 1990s, especially acidification, eutrophication and climate change. All three of these were really starting to form stable actor-networks during the 1970s and the 1980s.

From the mid-1980s onwards, the Environment* really started to grow both in size and stability. The end of the 1980s saw the emergence of a tool to capture the Environment*, namely life cycle assessment (LCA). All impact categories are gathered to form a single measuring instrument for the potential environmental hazards connected to any product. During the 1990s, the tool became widespread and aided the various impact categories in expanding as they were applied to still more products. Many studies were also performed within the automotive industry.
At the same time, work was performed to refine the impact categories of acidification and eutrophication and to control the emissions associated with them. A mixture of political and scientific processes led to the introduction of terms such as critical loads and limiting nutrient and other actors such as grid maps and oxygen levels in water. Emission quotas and emissions trading were also introduced as part of one of these hybrid processes. As acidification and eutrophication share some basic components (for instance, NO_x contributes to both effects), the impact categories became intermingled.

Global warming had been lurking in the background as a potentially important environmental impact category during the 1970s and the beginning of the 1980s, but it became real in 1988. It changed its name to 'climate change' at some point during the 1990s. This change of name is associated with a change in focus, from only looking at warming effects such as increased temperatures, ice smelting and rising sea levels to the inclusion of other climatic effects such as effects on ocean currents and changed weather patterns. Moving from the emission of greenhouse gases such as H_2O, CO_2, CH_4 and N_2O, to the absorption of infrared radiation in the atmosphere and changes in temperature, the impact chain had been recognised since the late 19th century. However, it took almost 100 years for the enhanced greenhouse effect to become a well-established scientific fact (although not undisputed). It required the connecting of numerous sciences (such as glaciology, meteorology, oceanography, chemistry, physics, computer sciences and mathematics), scientific articles in hundreds of journals, temperature measurements, scientific bodies such as IPCC, political processes such as the one connected to the Kyoto Protocol (where emission quotas and emission trading became enrolled) and a range of other actors to grant it stability.

After the turn of the millennium, the connections to climate change have continued to increase in numbers and even other impact categories like acidification have been intimately linked to climate change. In fact, the climate change network had in itself grown so large in 2006 that the other previously mentioned impact categories were almost invisible.

However, more and more concepts have been created, including sustainable development and industrial ecology, which have filled research with new hybrids consisting of the environment, the social and the economic. While these concepts are indeed involved in continuing the expansion of the climate change actor-network, they also lead to the inclusion of new impact categories – new elements in the Environment* – such as the category related to injuries, harm and safety.

Figure 4-27 below shows the Environment* as of 2006.

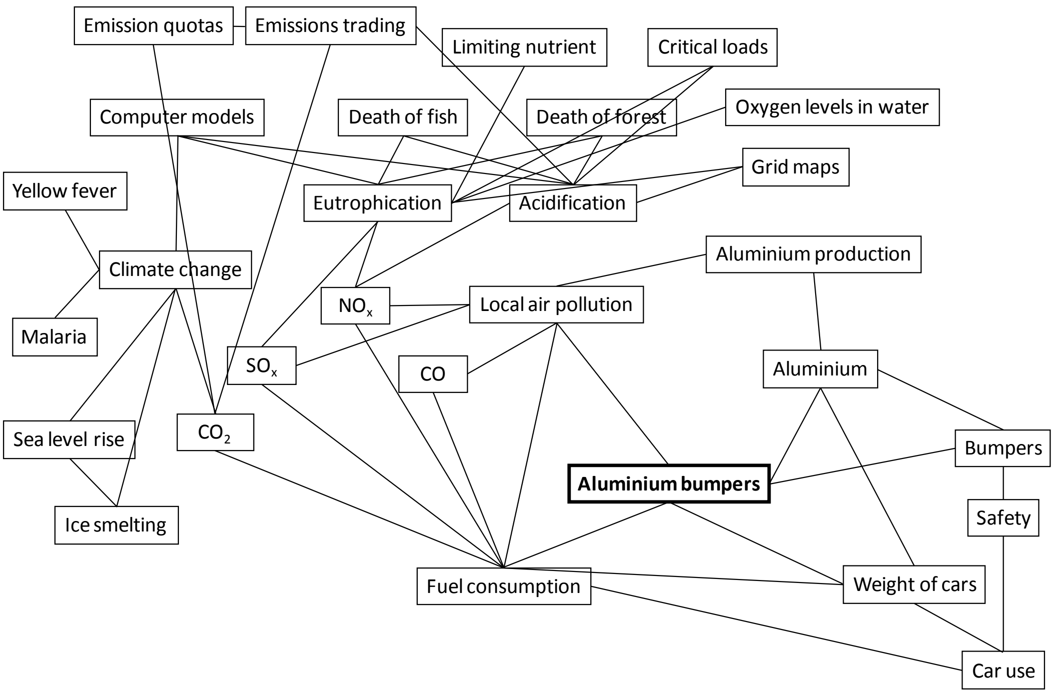

Figure 4-27 The Environment in 2006.*

The actors presented in Figure 4-27 obviously do not represent an exhaustive list of all the actors connected to the Environment* in 2006. They should, however, provide a large enough number of actors to make comparison with the actors, resources and activities from the Economy*. In order to structure the actors into a more accessible format, they are presented on a timeline in the next section.

4.5.2 Timeline of the Environment*

The actors, resources and activities presented in this chapter can be organised according to the time of their introduction or alteration as shown in Figure 4-28.

	Actor in the Environment*
1970[118]	Black-boxed versions of local air pollution
1971	
1972	Resource scarcity (re)appears and gets immediate attention
1973	Resource conservation in bumper texts
1974	Resource scarcity grows but is disputed
1975	
1976	
1977	
1978	
1979	
1980	Resource scarcity fades away
1981	Acidification and eutrophication make their appearance, but without major impact
1982	
1983	
1984	The bumper (or even the automobile) has almost disappeared from the environment
1985	
1986	
1987	Sustainable development introduced
1988	Global warming is "confirmed", critical loads are introduced
1989	LCA connects to SETAC, emission trading in acidification
1990	The first IPCC report
1991	
1992	The Leiden guide
1993	
1994	The second IPCC report
1995	Industrial ecology
1996	International Journal of LCA
1997	Kyoto meeting
1998	
1999	
2000	Global warming starts stealing all the attention, other categories fading, Thiel-article
2001	
2002	New Leiden guide, safety is included as impact category
2003	
2004	
2005	
2006	Global warming established as fact

Figure 4-28 Timeline of the Environment(the introduction or change of actors).*

118 The elements (actors) displayed in 1970 were already in place and were not introduced or changed that specific year.

4.5.3 An adjusted image of the environment

The Environment* did not look at all like the stereotypical view of the environment encountered in the introductory chapter. The emotional human actors we could have expected to meet have been completely absent.

Instead, we have met actors – often in the form of texts, graphs and figures – that have faithfully and thoroughly tried to unveil connections between actors in nature: the links between the emissions of numerous chemical compounds and real impacts on plants, water bodies, animals, ice, human beings etc. The texts could never have been produced without measurement technologies, laboratory equipment, rigid testing or computer models. However, we must remember that other factors – such as journals, scientific communities, political interests, pencils, transport means, maps, notebooks, universities, money and a lot of other actors - have been instrumental in the creation of such texts.

In order for anything to become an environmental problem, it is not enough for one article to have exposed a relationship between a potential stressor and a potential impact. For any element in the environment to last, it needs to be connected to others. From the text, we can see that it was the elements that were able to create many connections that seemed to last longer. Furthermore, the degree of heterogeneity of the actors to which the element is connected seemed to be important. The impact categories that have lasted the longest are all connected to a wide variety of other actors. This applies to both acidification and eutrophication. However, there is no doubt that no other impact category mentioned in the text has managed to develop as many relations with such heterogeneous actors as climate change. Over the last decade described here, it appeared to be more of a black hole swallowing all other actors than just a black box. Climate change started to become the only environmental problem worthy of attention after 2000. No other impacts can compare to it when it comes to the size or severity of potential effects. No other impacts are as intensively connected to most human endeavours. The co-production of environment and politics, as can be seen in much of IPCC's work, is also an important aspect of the climate change actor-network expansion. Generally, there has been a move towards more and more connection between politics and environment - as seen for all three impact categories included in the Thiel article.

Resource scarcity appears to be at the other end of the "importance scale". It never created enough connections to expand and get a strong foothold. In fact, economics as a science participated in defining resource scarcity (almost defining it away entirely). It may be claimed that this environmental problem was more closely connected to human perception and intervention than the others examined in this chapter, i.e. that later environmental problems have been more "natural" and outside human communities than resource scarcity. It is impossible to say whether it has been a deliberate strategy for scientists involved in environmental issues to turn away from environmental problems where economists may have definition power, or whether it is just associated with the problems that nature has to offer. However, a specific feature of resource scarcity as an impact category is that its formation was based on a general computer model. When 'reality' produced results deviating from the model, the impact category lost its impact. Nevertheless, resource scarcity is still lurking in the background in the later stages of the descriptions, as indicated (for example) by the inclusion of the impact category in an LCA article on car fenders.

In summary, the Environment* has expanded both in space and time. Although resource scarcity refers to global effects, the trend has shifted from the already black-boxed local impacts of emissions of the early 1970s to the regional impacts of acidification and eutrophication in the late 1980s to the all-encompassing impacts of climate change from the late 1990s. In relation to time, the local impacts were mostly acute, the regional with a certain longer time-span, while the global impacts have also incorporated an almost infinite view of time. The concern is not only here and now, but also how our grandchildren or their grandchildren will be affected by today's emissions.

Even if the Environment* has proved to be different from the stereotypical view of the environment, there are few, if any, elements that resembled the stereotypical view of the economy.[119] Whether the Environment has any resemblance or connections to the Economy* will be the issue for the next chapter, as will the mechanisms for establishing such connections.

[119] Except, maybe, for the rationality involved in the scientific endeavours.

5. Connecting the economy and the environment

You may have noticed that the asterisks connected to the words "economy" and "environment" have disappeared in the heading of this chapter. The capital letters and asterisks have been used to denote the part of the economy and the part of the environment that are involved in the life of bumper beams. In this chapter we are moving outside the Economy* and the Environment* into the larger (still undefined) networks of the economy and the environment. This is also being undertaken because I firmly believe that the descriptions of the Economy* and the Environment* (i.e. the elements they consist of) actually represent images of how the economy and the environment work.

The working of the Economy* and the Environment* was presented in the two previous chapters, including the important elements for each. Some of the fundamental questions about the working of the two networks have been answered in this text. The aim of the thesis was, however, not merely to produce two separate descriptions of the economy and the environment in isolation - the aim was to explore the space where the two networks meet. We thus need more insight into the connections between the Economy* and the Environment* to say something meaningful about the relations between the economy and the environment (e.g. what the relations consist of and how they came about).

Elements that are common to both networks provide connections between them and must be found and understood in order to understand the inter-relationship. The chapter starts with an attempt at finding such common elements, first by placing the timelines of the Economy* and the Environment* (as presented at the end of the two previous chapters) in the same diagram to see if any elements are part of both and then by including supplementary information from the empirical chapters. Some of the common elements are briefly presented. How these elements have become shared is the next issue and I will discuss the direct and indirect routes that the elements use to travel from one network to the other. Elements do not normally travel by themselves. They are helped by mediators – vehicles for translation – that accommodate the transfer between networks. The chapter ends with a description of such vehicles for translation.

5.1 Common elements in the economy and the environment

To understand the relationship between the economy and the environment, it is necessary to expose elements that are shared in both networks. Although the networks themselves are theoretical constructions, the empirical chapters showed that there are indeed differences in how the economy and environment are produced and sustained. Hence, the compositions of their elements are different. This means that most of the elements contained in the economy have no direct connections to elements in the environment (and vice-versa). Nevertheless, there are some elements that are present in both networks.

No network in society is able to live completely on its own. Every network's success is dependent to an extent on how it manages to connect to other networks and to establish itself as the carrier of the right idea. This is achieved in a process where important elements (or 'ideas') from one network are allowed or even forced to travel to another. The element may change character somewhat during the journey, but it should still be recognisable when considered from the perspective of the original network. It is almost like going in a supermarket in a country other than your home country. The items on the shelves appear slightly different, although still similar to those you find at home, but the names on the items are all different[120]. Translated to this thesis, this means that if an element travels from the economy to the environment, an economist should be able to tell that the element comes from the economy when it has become part of the environment (and vice-versa).

In order to pinpoint such elements present in both the descriptions of the Economy* and of the Environment*, it is useful to turn first to the timelines to see if any of the important actors, resources and activities (in IMP language) in the Economy* are similar to any of the important actors (in ANT language) in the Environment*.

5.1.1 A recollection of the timelines

In Figure 5-1, the timelines for the economy and the environment are placed alongside each other to see if there are any evident connections between important elements in the Environment* and in the Economy*.

[120] Of course not *all* brand names are different. It is highly unlikely that you will find a supermarket anywhere in the world without, for example, Coca Cola.

Actors in the Environment*	Year	Activities, Resources or Actors in the Economy*
Black-boxed versions of local air pollution	1970[121]	Bumper making, cast house, extrusion press, roll forming equipment, manual assembly, ÅSV, RA, Volvo
	1971	
Resource scarcity (re)appears and gets immediate attention	1972	Legal requirements, safety bumpers NHTSA
Resource conservation in bumper texts	1973	Oil crisis
Resource scarcity grows but is disputed	1974	Cast house, several new customers
	1975	
	1976	
	1977	
	1978	
	1979	Plastic forming technology, Statoil
Resource scarcity fades away	1980	Plastic forming
Acidification and eutrophication make their appearance, but without major impact	1981	Paint factory established at Raufoss
	1982	Roll forming ends
	1983	
The bumper (or even the automobile) has almost disappeared from the environment	1984	
	1985	
	1986	Hydro acquires ÅSV, ALPROFIL is dissolved
Sustainable development introduced	1987	First hollow bumper beams
Global warming is "confirmed", critical loads are introduced	1988	
LCA connects to SETAC, Emissions trading in acidification	1989	
The first IPCC report	1990	Volvo and Renault form strategic alliance
	1991	
The Leiden guide	1992	
	1993	Introduction of LS-Dyna at Raufoss Volvo and Renault want to merge, but fail
The second IPCC report	1994	Bumper and bumper beam departs Hydro acquires 40% ownership of RA
Industrial ecology	1995	New cast house, introduction of platform strategy
International Journal of LCA	1996	Casting increased
Kyoto meeting	1997	Hydro acquires rest of RA
	1998	Plastics production is moved, introduction of HAPS
	1999	New extrusion press, several new documents introduced, Ford acquires Volvo
Global warming starts stealing all the attention, other categories fading	2000	Hydro sells "plastics"
	2001	
New Leiden guide, safety is included as impact category	2002	
	2003	New supplier policies from Ford
	2004	
	2005	
Global warming established as fact	2006	

Figure 5-1 The timelines of the Environment and the Economy* placed together*

[121] The elements (actors, resources and activities in the Economy* and actors in the Environment*) displayed for 1970 were already present and were not introduced or changed that specific year.

The first thing you notice about Figure 5-1 is the almost complete lack of similar elements in the two networks. Although spotting similar elements requires knowledge about what the short descriptions in the figure contains, few obvious common elements are present. In fact, it looks like one story of elements that have contributed to creating the economic properties of bumper beams and a completely different story of elements that have participated in the creation of the environmental characteristics of bumper beams. One reason may be that the timelines were produced to highlight the most influential changes in the Economy* and the Environment* respectively, and thus minor events in each of the networks were left out. There may still be common elements between the two networks that have not been instrumental in any of the economic or environmental changes of the properties of bumper beams. In other words, some parts of the Economy* may be part of the wider environment without being part of the Environment*, whilst some parts of the Environment* may be part of the wider economy without being part of the Economy*.[122]

The finding (or perhaps non-finding) of few common elements reminds us how little the two networks influence each other, which again may be one of the reasons for the perceived conflict between the economy and the environment as described in the introductory chapter of the thesis. The content of each of the networks was, however, different from the stereotypes given in the introduction.

In fact, the only elements with a resemblance in the two networks are the pairs "resource conservation" – "oil crisis" and "local emissions" – "paint factory at Raufoss". They may not seem similar at first glance, but once you understand what the terms imply, they become entangled and almost equal. This point is further elaborated in the next section.

In theory, it looked like it would be easy to make connections between the environment and the economy, just by transferring elements from one to the other. However, the text from the previous chapters shows that, in practice, it is hard work to make elements count. The next section gives a brief overview of some elements that have managed the task and are shared between the two networks.

[122] A practical consequence for the remainder of this chapter is that other information from the empirical chapters has been included (in addition to what was included in the timelines).

5.1.2 A short description of shared elements

The first element found in the case descriptions of both networks is aluminium use. The idea of light weight connected to aluminium use has been connected to elements in both the economy and the environment throughout the entire time span covered in the empirical material. This idea was further reinforced by the introduction of the concept of resource scarcity. It shows up as a highly relevant environmental category in the early 1970s and, a few years later, as an important argument for choosing aluminium bumpers in the economy. The concept refers to the possibility of running out of natural resources and much of the underlying scientific material was coupled to oil consumption. Meanwhile, oil consumption in itself is also an element shared between the two networks and an element that later shows up connected to other environmental elements. In both periods where oil consumption has been the focus, it has also been connected to the issues of light weight and fuel consumption in the economy. In the environment, it was first connected to the danger of losing a resource (although partly coupled to local emissions that were shared between the economy and the environment from before 1970) and later coupled to climate change.

Aluminium use has been connected to aluminium production in both networks. The production of aluminium alloys of the right quality created difficulties in the economy in the early 1970s, while the emissions (especially fluorides) have been an important element in the environment. Towards the end of the 1970s, however, aluminium production created fewer difficulties for the networks. With an increased focus on recycling in the environment during the 1980s, aluminium production and use started to be viewed as more environmentally friendly. However, recycling did not make much impact on the economy connected to the bumper beams, as the companies never managed to create an efficient recycling system.

Test vehicles were found to have an impact on both the economy and the environment. They are used for finding new designs, processes and materials in the economy; when these have a lower impact on the economy, they are taken up by the environment as examples of possible future directions.

Local emissions of harmful substances became a factor in the economy in the early 1980s due to tighter Swedish legislation. There are traces of this element being connected between the networks earlier on, but it is invisible until the legal network becomes involved. The setting up of the paint factory at Raufoss was one of the physical and visible consequences.

The two companies started using LCA in the late 1980s. This method was instrumental in assembling various environmental impact categories in the environment and creating an environment that focused on more than one possible problem from one possible source. In the economy, it also introduced new environmental concerns (e.g. acidification, eutrophication and global warming) and wider boundaries for the environmental elements in the economy (i.e. introduction of responsibility for phases other than just the companies' production phases, e.g. raw material acquisition or the end of the useful life of the products).

Trade came in as an element in the early 1990s. Being one of the building blocks always present in the economy, it suddenly showed up in the environment as one way of tackling emissions of medium- and long-range pollutants (i.e. pollutants that have an impact on places other than where they were emitted, e.g. NO_x and SO_x). This element was further reinforced as being a natural part of the environment when it was introduced as part of the science dealing with climate change, e.g. where CO_2 quotas have materialised.

Models for climate change have even imported imaginative decision-makers, in order to make them agree on the valid time frame for analysing different scenarios. The companies (in the economy) and the environment are thus given an opportunity to create a relative environment, depending on perspectives for the future.

Towards the end of the 1980s, sustainability became an important word in the environment and its influence has grown over the years. Around the start of the new millennium, sustainability really made its mark in the economy as well, at least in the part of the economy busy creating printed material, as sustainability reports became something companies (at least Volvo and Hydro) should do. That the concept is shared between the networks should be no surprise, considering that it encompasses both economic and environmental issues in addition to social issues.

Safety has always been an important point in the economy connected to bumpers, particularly after the introduction of the 1972 Safety Act in the USA. Since the year 2000, the concept of safety has also started to become an integrated part of the environment. The boundaries between safety from environmental harm and from accidents are slowly fading away as both issues are now included in environmental analysis.

Timeframe is an important factor when looking at the elements that are shared. Sometimes elements may transfer more or less immediately between the networks, while in other cases it may take years. It is useful to bear this in mind when examining the transference of elements between the networks.

5.2 Direct routes that connect the economy and the environment

This section intends to give examples of the ways in which one of the networks connects to the other and of the direction of flows. It shows two different examples of direct travel routes between the networks and touches on the consequences of the specific travel routes for each of the networks.

5.2.1 The first route: directly from the environment to the economy

The first route investigated is the one where properties from the environment are transferred directly to the economy. The most obvious example of this route is the everyday practice of industry where natural resources are employed to create economic outputs (which can then be employed in other networks). However, these transfers of natural resources and money are partly disconnected from a discussion of the networks, because they are so well black-boxed that they are almost never an explicit issue. What the empirical material has focused on is those issues that have questioned what the networks really consist of, or that have tried to expand or alter the networks' compositions. Even though natural resources and money are intriguing and difficult concepts when one starts to think about them, they are so well integrated into most human activities that they are taken for granted. How could anything be produced without input of natural resources? And how could the economy be sustained without the means of money? These questions could form the basis for numerous theses, but are not treated extensively here. Rather, the following section will discuss examples where controversies exist, such as where new entities in the environment are transferred to the economy.

The method of life cycle assessment (LCA) could have been an example of an indirect route, where something from the environment was translated to the economy through the political and/or legal network(s). The US Environmental Protection Agency, however, turned down the idea in the beginning of the 1970s that REPA (the historical predecessor of LCA) could be used to control impacts on the environment caused by industry. Nevertheless, many companies started using the method and it represents the possibility of direct introduction from science to industry, hence its inclusion in this discussion of the first route.

Volvo was a relatively early adopter of LCA and even contributed to the development of weighting tools for LCA through its involvement in developing the Environmental Priority Strategy EPS system from 1989 onwards. According to Resetar et al (1998):

> "Two important factors that contributed to the success of the EPS project were the support of experienced, senior management on the industrial side (e.g., the Volvo Group Vice President) and knowledgeable scientific researchers. Generally, industry members worked with the scientists to build consensus on the model ground rules and system boundaries. The scientific details were left to the scientists" (p. 110)

A weighting tool like EPS is a ranking scheme for various environmental impacts to support a simpler comparison of the environmental consequences of a product. LCA and EPS were thus accompanied by the involvement of numerous environmental categories and even consideration of what to save the environment for and from. Volvo was also made more aware of the entire life cycle. No longer was it enough just to control the company's own processes; even the product itself had to ensure environmental "savings", including the cars' use phase and after the end of its useful life.

Information from LCAs began to be published along with more technical information for consumers. Today, customers can go to the Volvo homepage and compare the environmental performance of different Volvo models. Volvo also tried to employ LCA as a design tool to make environmentally informed decisions in the development of new models, but this has stopped as, according to an environmental manager at Volvo: "We always know what the result will be. Emissions of CO_2 will overshadow everything else." Instead, they use simple checklists to ensure that the issues of chemicals use, pollutants and weight reductions are included in the development of products and processes.

Hydro was also an early user of LCA, but apart from a study of the bumpers, there was little cooperation in this field between the two companies. The use of LCA did, however, mean that the two companies could communicate about environmental issues with a common language connected to life cycle thinking.

If we follow the trails to those who commission LCA studies in industry, we normally end up in an environmental department. Such departments themselves often contain examples of the first route. The environmental department is set up to communicate environmental issues inwards in the business organisation by translating elements from the environment into elements that are understandable in industry. For instance, when there is a change in the environment that may affect business, the environmental department is responsible for tackling this.[123] To be able to perform such a role, the department must be equipped with environmental competence. Thus, there are theories or theoretical elements travelling directly from the environment to the economy. If you visit the environmental departments in either Volvo or Hydro, you will find that several of the people have been educated in environmental studies. The people themselves (or perhaps rather the competence they bring) are transferred from the environment to the economy. However, there is a danger that they may lose their connections to the environment if they do not succeed in continuing with links to scientists involved in producing the environment.

Another example where the environment is transported directly into the economy is in the form of test vehicles. Not all test vehicles come into this category, simply those that are specifically developed to pollute less. Few ordinary cars demand the use of extensive research.[124] To keep costs down, known methods, machinery and materials are employed. Alternative materials, designs, propulsion systems and ways of manufacturing are tested in so-called test vehicles. We encountered a few examples both in the description of the Economy* and of the Environment*. In addition to being a test of what cars can be produced in the future, surveys are performed both in literature and in industries to see what technologies exist. The Light Component Project car discussed in the Economy* case was one such test vehicle, accompanied by research by Volvo and the suppliers.

A simple sketch of direct travel from the environment to the economy is given in Figure 5-2.

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[123] "A change in the environment" refers to new elements (actors) being emphasised; for instance an increased focus on one environmental impact category on the expense of others.

[124] Although there are certainly high development costs, these are mostly related to known processes and materials.

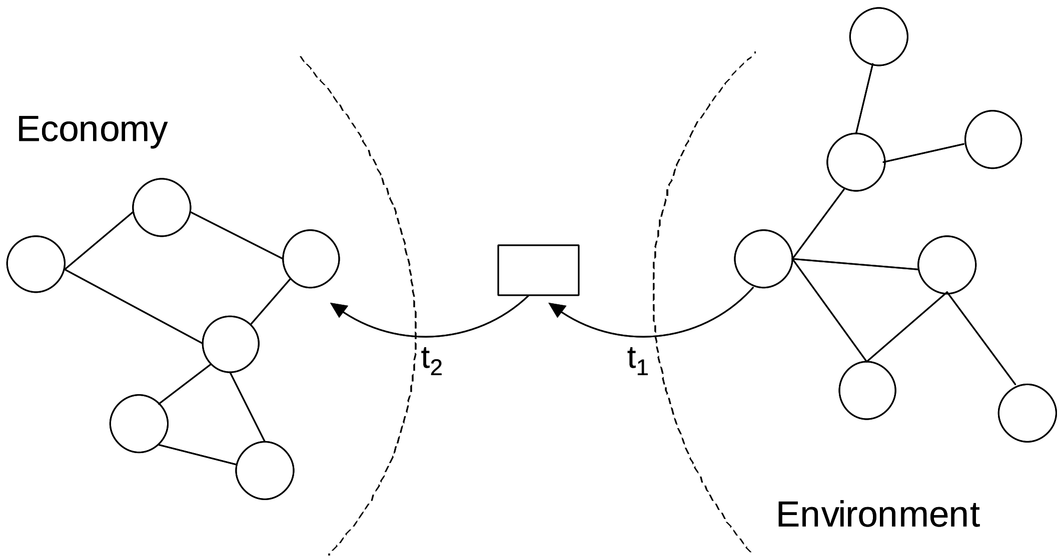

Figure 5-2 Elements travelling directly from the environment to the economy.

The diagram shows how an element is made ready to travel from the environment at t_1, while at t_2 the connection is made to other entities within the economy. The element that moves has to retain connections to nodes within the environment in order to be a true connection point. A more thorough description of the way elements move is given under the discussion of vehicles of translation in Chapter 5.4.

To an ethicist, this route may be comforting. The possible betrayal of the 'pure' environment is short-circuited by introducing the environment directly into the economy. A further plus is this route's ability to create a positive attitude towards the environment amongst company employees. The environment that is brought into the organisation may make it easier for the employees to defend their working in an industry that is attacked for being polluting. Another positive element, connected to that covered above, is that companies can control the costs for environmental measures better, as they choose the level of commitment themselves.

Still, it means less force is put behind the environment. No control mechanisms are in place to check that there is compliance between the companies' voluntary environmental claims and their actual resources and activities. Hence, this route may give business actors an environmental identity without being connected to an alteration of activities and resources in a more environmentally friendly direction.

In summary, this route has a positive flavour due to its high degree of voluntarism. The danger is that companies may decide to do nothing other than employing an "environmental" language.

5.2.2 The second route: directly from the economy to the environment

As for the first route, there is also an obvious route for transporting elements from the economy directly into the environment, i.e. the use of financial resources to create scientific outcomes. New descriptions, re-descriptions or confirmation of old descriptions of the environment are dependent on the economy. Financial resources are needed to carry out environmental research and industry is responsible for developing and manufacturing artefacts needed for producing science (from pencils, notebooks and printing presses to complicated machinery for running experiments). Although there may be instances with heroic truth-seeking researchers who devote their lives to wrestling with nature and all its secrets, the spreading of such knowledge is intimately connected to organisations, journals, book printing and other capital-intensive technologies, as described in the chapter on the Environment*. The economics of research are seldom discussed in environmental articles, yet there is an inevitable link between the research performed and the money ready to support research. However, as for the first route, travel directly from the economy to the environment is more concerned with the ideas that travel than the physical resources - although these are often entangled.

The environmental research performed in industry is an obvious example of this route. Thus, the Thiel article, i.e. the starting article for capturing the Environment*, is yet another example of one element (or more) travelling from the economy to the environment. The content transferred into the environment was an empirical matter - the emissions related to aluminium bumper beam production. It gave an example of how industry creates environmental properties. In addition, by focusing on three specific impact categories (acidification, eutrophication and climate change), the article contributed to stabilising the contents of the environment. The strength of environmental categories lies in their employment and the Thiel article is participating in the definition of what constitutes an important category.

More generally, articles produced in industry for the environment contribute to defining what materials and production processes are actually used and should therefore be the objects of study for the environment. The environment is seldom absolute and the viable industrial alternatives usually define what good environmental practice is.

Another example of an economic practice participating in defining the environment was shown in the construction of the 'resource scarcity' impact category. The impact category lost its momentum as the result of industrial improvements in processes (as well as better estimation techniques).[125] Even if, perhaps, it contained a true description of a serious problem, the economy responded and dissolved the whole actor-network termed 'resource scarcity'. The consequence was not just that resource scarcity vanished as an impact category; it also paved the way for focusing on other issues - other environmental problems - thus indirectly affecting the course of the environment.

Although the thesis has not looked in great detail at the models underlying the way activities, resources and actors are organised in business, references have been made to how production philosophies from Japan spread in the 1980s and thereafter. These production philosophies contain ideas about production with zero waste and have influenced the way environment is depicted, e.g. in industrial ecology. Common terms have been used to describe industrial and natural life, and environmental scientists have developed terms describing resource efficiency that were not present earlier.

The environment has become all the more calculable, partly as a consequence of being included in accounting (Asdal 2005). Although it did not show up in the Economy*, both Volvo and Hydro have included environmental figures in their annual reports. The way the environment is described in terms of balances of inputs and outputs is made to resemble the way accounts are recorded in business. This way of presenting environmental figures has contributed to make the environment even more numerical and disconnected from nature.

Both companies have been and continue to be involved in sponsoring universities, professors and specific university programs. For example, the initiation of the Industrial Ecology programme at the Norwegian University of Science and Technology was very much due to Rolf Marstrander in Hydro Aluminium. He had heard about the theoretical concept and initiated a project group and financing. This is, again, a direct link from the economy to the production of environment. Yet, despite close connections between industrial ecology and the company Hydro in general, and Hydro Aluminium in particular, the production site at Raufoss has not been able to close the loop. The project initiated to recycle the bumpers and later bumper beams

[125] This is not referring to the economists involved in the scientific debate on the "resource scarcity" issue. On the contrary, these economists probably kept the category alive even longer by creating engagement amongst environmental scientists.

from Raufoss was abandoned, as the material collector in Sweden demanded too high a price for the end-of-life aluminium. The rhetoric may be in place, but ideas about industrial metabolism have not materialised due to financial constraints. The refrain is "we have to stay in business in order to implement environmental measures." – implying that the finances must be handled first. Even if travel from the economy to the environment has been smooth, the journey back again (according to the first route) has failed. This is perhaps no surprise, as the commitment has only been to provide economy for the environment, not the other way around.

A simple sketch of the route directly from the economy to the environment is shown in Figure 5-3.
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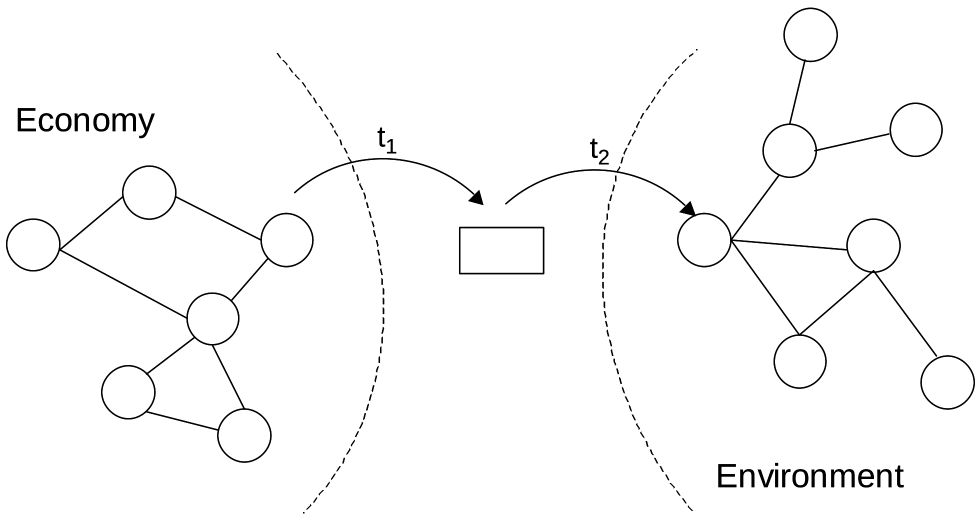

Figure 5-3 Elements travelling directly from the economy to the environment.

The environment has become affected by elements introduced from the environment and it is clear that that economy influences what the environment is by 1) altering the ways the environment is defined, 2) giving support to some environmental issues but not others, 3) providing ideas about resource efficiency and 4) providing finances for specific environmental programs. Therefore, the economy both introduces new actors to the environment and alters those already present.

There is a danger for business activities if the transfer has not been completed to the degree where laymen understand the economic elements as belonging to the environment. Companies are easily given the blame when the environmental label is put on practices that the outside world understands as economic. The danger of this direct route from the economy to the environment is that if it fails to make its way into legislation, the public may see this action as a false attempt at creating an environmental image, instead of environmentally sound practice. Thus, even if both the costs for the company and the environmental impacts are reduced, there may be adverse effects on the revenue side. Neither Volvo nor Hydro has experienced this phenomenon to a degree where it has been publicly discussed (or taken up by any of the interviewees). There has been no investigation of whether failed attempts by the companies to communicate environmental friendliness have had any impact on individual purchase decisions. There are, however, examples from the automotive industry of companies who have been punished for arguing too loudly about their outstanding environmental performance when the public have disagreed with the way it has been presented. You may say that there are few automobile purchases that are made on the basis of environmental criteria, meaning that the monetary punishment, i.e. the decrease in revenues, is relatively minor. However, the niche market that actually finds environmental criteria important does not accept false claims about environmental friendliness. Advertising standards agencies in several countries have received complaints about misleading ads - for example, Lexus had to withdraw a campaign in the UK (Anonymous 2007).

5.3 Indirect routes that connect the environment and the economy

There is no reason to believe that elements from any of the two networks can only be transferred directly between them. The descriptions of both the Economy* and the Environment* contain examples of connections to other networks that are involved in the transferring of elements. This section gives examples of indirect routes along which elements can travel between the economy and the environment.

5.3.1 The third route: from environment through other network(s) to economy

When thinking about how the environment and the economy are linked, one of the most obvious routes to imagine is that environmental issues are produced by science, translated into legislation and transported into the economy as constraints on production. The environment is thus often part of the unseen restrictions imposed on industry by governments and of the management tools that ensure compliance with such restrictions. In other words, the environment is inserted into business in the shape of rules and regulations affecting choice of technologies and materials that can be employed. This means that the environment only comes to the fore in economic life when it poses constraints or opportunities, and these are often already translated into economy, frequently in the form of a cost. Of course the environment is also present in the shape of the reservoir where inputs to production are collected and where emissions from production are disposed of. There are several examples of this third route connected to the bumpers produced in the relation between Volvo and RA/Hydro.

In the chapter on the Environment*, we saw that impacts from local emissions of pollutants were already black-boxed in 1970.[126] In fact, they had already made their way into legislation. Organic solvents from paints are examples of such local emissions. Although regulations were already in place during the 1970s, it was only when legislation was strengthened at the beginning of the 1980s that Volvo had to cut down on emissions from their paint factory.[127] The solvent emissions limit had direct consequences for the development of the plastic cap. First, Volvo chose an unpainted version to avoid the need for extra painting. This was connected both to environmental arguments and to avoiding extra costs. When the legislation was further strengthened in 1980 at the same time that Volvo decided to use painted bumper caps, RA had to set up facilities for painting at Raufoss, otherwise Volvo would have exceeded its emissions limit at Torslanda.

The example shows how scientific knowledge translated into legislation (e.g. emission limits on pollutants) has had a direct effect on the actors, resources and activities involved in producing bumpers. We understand that two other networks were involved in the travel from the environment to the economy even without following the trails, namely the political network and the legal network.

You may say that the example involves a paradox, as the total emissions of pollutants probably increased rather than decreased - RA had to build a whole new facility and probably had less ability to control emissions because of smaller volumes. The important point here though is that the environment was still local at the beginning of the 1980s. The idea of relating environmental policy to products and chains of producers to ensure that emissions are lowered per product was still more than a decade away.[128]

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[126] Local emissions denote the pollutants that are transported only over short distances and hence only create local impacts.

[127] I have not managed to find a scientific rationale for the strengthening of the environmental law, as it does not contain references to any scientific articles and my study did not take me outside the networks of the economy and the environment.

[128] This later development may also involve a paradox, as it does not consider whether there is an increase in output.

The other prominent legislation in the case was the bumper standard included in Federal Motor Vehicle Safety Standard 215 in the USA. Although the standard focused on safety, which was not part of the environment at the time it was enforced, it demanded that stronger bumpers should be mounted on cars. To avoid excessive weight increases on cars, the carmakers were pushed to find materials other than steel. Aluminium was the strongest candidate. The environment was involved indirectly, as the connection between the car's weight and its emissions was a part of the environment. This instance of the environment travelling to the economy via legislation is, however, not as clear-cut as the example with limits on emissions of organic pollutants from the paint factory.

Over the last two decades of the period covered in the case, the scientifically produced environment has had an even greater impact on legislation, with the focus being placed on the contribution of pollutants such as NO_x, SO_x and CO_2 to acidification, eutrophication and climate change. Scientists have been instrumental in determining the acceptable emissions levels. At the same time, legislation has become more and more product-orientated. There has been a shift from focusing on point sources for emissions, i.e. the production facilities, to the entire life cycle of products. This has led to so-called "extended producer responsibility", where the manufacturer of the final product is responsible for the environmental impacts all the way from the acquisition of raw materials to the disassembly of the product and the recycling or disposal of materials. This change has also put pressure on the carmakers to increase their knowledge of environmental impacts, as they must be able to handle environmental impacts other than those directly related to their own production sites or the use phase of their products.

A simple sketch of the general route of elements travelling from the environment to the economy through mediator(s) is shown in Figure 5-4.

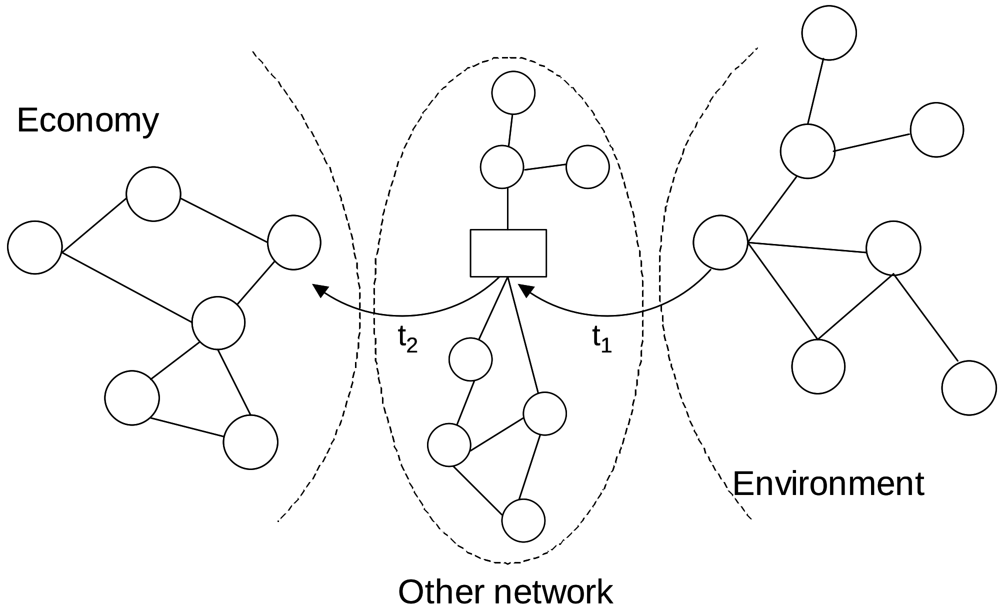

Figure 5-4 Element travelling from environment to economy through mediator(s).

The diagram shows how an element from the environment is brought into another network at t_1, (usually the legal network), where it is connected to other elements (usually legislation). The element then travels to the economy at t_2, together with some of its newly established connections.

To some occupied with ethics, this route may be troublesome. The route involves translating the environment into entities that are more pressing in the daily life of the companies. Thus, one may claim that the environment is taken into account (almost literally) for the wrong reasons, not to save the environment but to avoid some kind of punishment such as a fine or a forced stop of continued production (i.e. for economic reasons only). This means that companies are then likely to refuse to take a proactive stance and emissions will only be reduced to the legally acceptable level. Furthermore, by being introduced via the legal network with threats of fines, it is unsurprising that companies see the environment as being a burden.

The environment then continues to view the economy as a network that only thinks about sustaining itself and does not consider wider consequences for the planet.

This indirect route presents a real possibility of inducing changes in the economy, where activities and resources must be aligned to the demands posed by legislation. It may therefore be a viable route for making changes happen. There is, however, a danger that the detour through other networks makes the element transform into something with too much flavour from the legal network and too little from the environment. For instance, it may be that many compounds become nothing more than a legal level, rather than reflecting all the information about the potential consequences of releasing it into nature. This may also create adverse effects on elements in nature, when legislation forces measures such as recycling systems instead of encouraging and supporting decreases in the use of natural resources in the first place (in the design phase).

5.3.2 The fourth route: from economy through other Network(s) to environment

While the third route may have seemed obvious, the fourth one, involving the transfer of elements from the economy to the environment via one or more other networks, is less so. This may stem from the image of the environment as something in need of protection from the ruthless economy, while the economy has been so busy with its own development that it has had no interest in trying to influence what the environment is through alliances with other networks. There are, however, examples of industrial practice that have been taken into the environment through a third network.

When regarding the environment as consisting of all natural resources creating input to industry, this route perhaps appears as normal as the previous ones. There are numerous examples of the problems faced by the economy that have been regulated before they have become part of the environment, the scientifically produced environment that is. Such examples include waste handling issues and work-related hazards.

As explained in the methods chapter and in the chapter on the economy, the basic working of the economy is exchange and constant attempts are made to lower the costs for both parties involved in the exchange. In order for exchange to take place, the object of exchange has to be specified, or commodified, so that property rights can change hands. The environment has resisted commodification for a long time, but during the work on acidification legislation in the USA, trading schemes were developed by economists and mixed with elements from the environment to produce a market for trading emissions. In the Kyoto process, when submitting proposal about what the Kyoto protocol should contain, the US delegates suggested the inclusion of emission quotas. As we know, CO_2 quotas and the trading of emissions became a reality in the Kyoto protocol and it also affected the research process on climate change afterwards. CO_2 emissions became calculable, tradable entities suitable for exchange. However, although the transport industry is covered by the Kyoto protocol, the aluminium industry is not. Thus, business opportunities may be created for aluminium bumper beams as a consequence of the protocol. Car manufacturers have used the development of engine technology as the main instrument in order to decrease fuel consumption and improve emission standards over the last few decades. However, the development still cannot pass the theoretical limits, which makes aluminium (or other lightweight materials) ideal for reducing weight and hence fuel consumption and emissions.[129] As a result, the inclusion of this element from the economy in the environment has provided aluminium bumpers with a competitive advantage in the economy.

A simple sketch of this route is given in Figure 5-5.

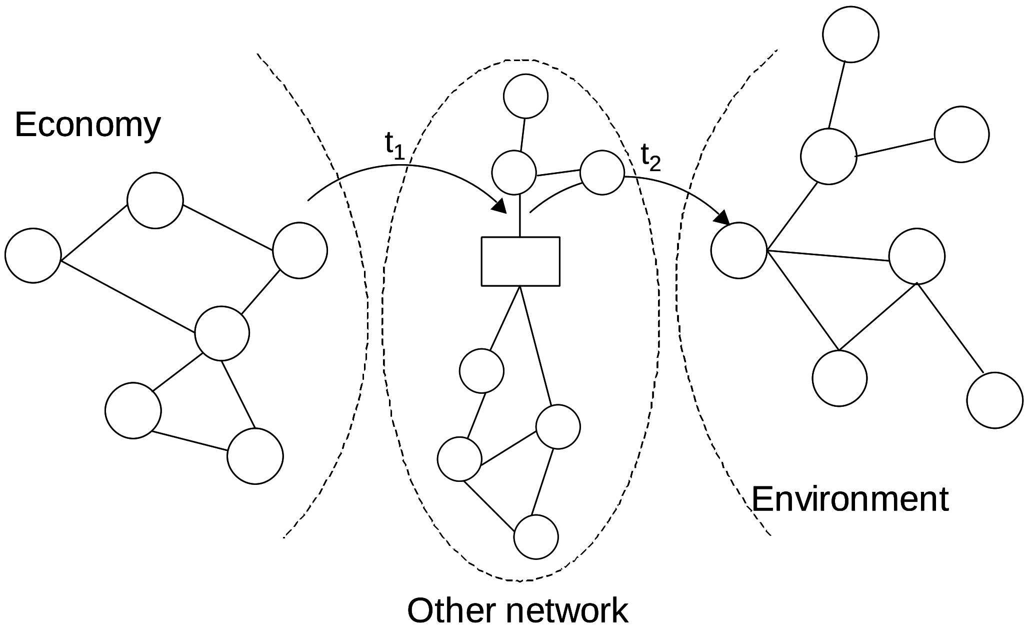

Figure 5-5 Elements from economy travelling to the environment via other network(s).

[129]The Volvo series of smaller cars have therefore always had steel bumpers (obviously not produced by RA or Hydro), as most cheaper cars do.

The diagram shows how an element from the economy is brought into another network at t_1 where it is connected to other elements. The element then travels to the economy at t_2, together with some of its newly established connections.

A similar opposition may exist in relation to the fourth route as to the third route, namely that the economy is translated into an entity not reflecting the true content of the economy. Instead of transporting all the processes and details necessary to produce efficient exchange in the economy, only a schematic image of the economy enters the environment. Thus, in addition to affecting the environment, the travel also reinforces the opinion of other involved networks that the economy-network is only occupied with a naïve form of buying and selling.

There are also many voices arguing against setting a price on nature, which is often said to be priceless. Although emission quotas put a price on emissions, they indirectly value the potential impacts stemming from the emissions. Where the environment has often stopped at a stage between the emission and the real impact (the stage of increased temperature in the case of CO_2 emissions), the inclusion of economy makes the environment stop even earlier – at the emissions stage. All the knowledge connected to the pathway of emissions becomes hidden and the level of emissions becomes connected not to the tolerable levels in nature but to a (some would argue artificial) market, as it is derived from political targets. The fourth route thus encourages actors in the environment to focus more on politics and the economy than science.

5.3.3 A summary of travel routes

The economy and the environment are connected by transferring elements from one to the other. This can be done either directly between the networks or indirectly through another network in a total of four different ways, as summarised in Table 5.1 below.

Table 5-1 Characteristics of the different travel routes.

		Example	Consequence
Direct	Environment – Economy	LCA imported into the economy directly from research institutions.	Elements are transferred in original state, retaining connections in the environment while being present in the economy. Small incentives for creating strong bonds to nodes in the economy.
	Economy – Environment	Materials, production technologies and philosophies imported into the environment from articles or reports.	Defines what elements the elements in the environment are related to (e.g. what industrial processes need to be assessed). Accusation of false claims if connections to elements in the environment are too weak.
Indirect	Environment – Economy	Environmental element brought into legislation. Legislation enforced in economy.	Binds elements from the environment to elements already present in the economy. Elements from the environment are connected to elements from other networks and may change character. Increased pressure in connecting.
	Economy – Environment	Emissions trading included in climate change after commodifying CO_2	The original element from the economy may be distorted, creating a stereotypical view of economy in other networks. May hamper the connections from stressors to consequences in the environment.

Table 5-1 shows examples of the four different routes and what consequences travelling the routes may bring. Travelling a direct or an indirect route creates different consequences for how the elements are perceived upon arrival and also for what connections the elements carry. Networks are therefore affected by the way in which the transfer occurs. Indirect routes lead to a greater risk of altering the original element as it becomes connected to elements in the network(s) it travels through. There is also a greater chance of the element actually becoming connected at the final destination, because the extra nodes connected to the element lend it more weight.

The words 'direct' and 'indirect' may imply that one is simpler and/or faster than the other. There is, however, no reason to suspect that going directly from one network to the other is easier than travelling an indirect route. The important factor is how easily the element can be assimilated into the network it is travelling to. A detour to another network may therefore make the transfer both faster and easier. The legal network, for instance, contains elements to control actors, resources and activities in the economy, but it does not in itself produce the desired direction of control. This means that elements from the environment, e.g. the specific polluting substances and threshold values for emissions, are inserted into legislation almost without alteration. The resulting laws and regulations are transferred to the economy in a known format and although the actors in the economy may lack the knowledge on how to act technically on the environmental measures that must be carried out, they normally have enough know-how to understand and relate to the specific legal texts, as legal texts are also used to control elements from the economy in the economy itself.[130]

The statement that elements from the environment travel in this way to the economy without alteration is only partly true. Although the names of the compounds and their dangerous levels of emissions are carried from one to the other, they do change character, as they are disconnected from many elements that are present in the environment. In other words, the concept of 'carbon dioxide' in environmental text is different from 'carbon dioxide' in legal text within the context of the economy – but the basic element can still be identified as the same in both.

Elements do not often travel between the networks by themselves. They need other elements to facilitate such travel. The other elements – the mediators – are designated vehicles for translation and covered in the next section.

5.4 Vehicles for translation

The different examples of travel routes between the economy and the environment have shown that there are a range of different mediators (also referred to as 'transporters' or 'vehicles for translation') between the economy and the environment. Vehicles for translation are routines, reports, organisations, human beings or other actors (using ANT terminology) that transport an element from the environment to the economy or vice-versa. The following is an attempt to lift these mediators out of the analysis to look

[130] Legal texts have been instrumental in defining and developing fundamental elements in the economy, such as property rights (see for instance Polanyi (?))

at their characteristics. First, however, we need a more detailed definition of the premises that allow the content of one of the networks to travel to another. This will be followed by a description of some of the different mediators.

5.4.1 Ideas are more or less substantial

An idea within somebody's head can be the foundation of creating new business practices or producing scientific findings.[131] However, in order to become more than an idea in the head of a single individual, it has to be rendered material in some form. A direct consequence of following this line of thought is that ideas have to be situated in actors (to use ANT terminology) or in either actors or resources (to use IMP terminology). This is confirmed by Welch and Wilkinson (2002), who write: "Idea logics are confounded with actors and resources in the current AAR model…"[132] However they continue the sentence by: "but [idea logics] have their own character and structure which impacts on network structure and operations, and interacts with the other three dimensions."

Håkansson and Waluszewski (2002) also differentiate between an image level (where ideas reside) and an activity level (where actual actors, resources and activities reside):

> "The idea structure is important in relation to the activated structure in at least two ways. First, it is an interpretation of the activated structure, providing an analysis of why it works as it does, including an interpretation of the technology involved. Second, the idea structure can also be seen as a source for making conscious changes in the activated structure" (p. 74).

This divide between an idea structure and an activated structure is introduced to explain that industrial systems consisting of heavy (both in terms of finances and weight) machinery may be difficult to change. That is, the activated structure imposes constraints on what ideas can be pursued so that even clearly good ideas become hard to implement. Examples of this were seen when the 'safety bumper' was introduced, when plastic caps were introduced and when the bumper beam became hollow. For the latter, the idea was to make a lighter bumper beam with crash characteristics that were as good or even better. Although the idea in itself should mean less cost as

[131] According to ANT thinking, it is perfectly possible that non-humans may also carry ideas, but understandably they are hard to explore.
[132] The AAR model is identical to the ARA model - they have just switched the letters round.

less material has to be employed, the resultant difficulties with adjusting the activated structure created losses for RA and later Hydro.

Such an argument for stability may appear to conflict with ANT's basic assumption about a world in flux in which stability requires explanation. However, it can be argued that any sustaining production network consists of a number of black boxes – technologies that are so well established and so interwoven with each other that they are taken for granted. Existing production technologies fit well with the idea of such black boxes - and black boxes are, by definition, stable. Furthermore, there is no separation between ideas and actors in ANT. Ideas can be actors, as well as the common denominator of an actor-network. The stability of ideas is also connected to the material degree of their composition. We saw in the Environment* chapter that the credibility of scientific texts is assured through the material composition (or 'heaviness') behind the results. In other words, for an idea to be deemed trustworthy, it needs to establish connections to a number of physical entities.

In light of this, my claim is that ideas are more or less substantial. This may have consequences both for their ability to travel and for the impact they can produce on the economy or the environment. To say that ideas are substantial is not to say that they are things if, by things, one understands a separate entity with physical presence. A substantial idea is also an idea put into words and made ready to travel through texts. This form of ideas is the one most largely employed in science, where the use of referencing and journals has cemented its position. Such a concept of 'ideas-as-text' (as shown in the chapter on the Environment*) is also frequently connected to a wider network of physical entities, including thermometers, laboratories, computers etc.

The description of the routes for connecting the economy and the environment may have given the impression that something, in other words a clearly delimited entity, is carried from one network to the other, meaning that the entity completely leaves the first network to become part of the other. However, this is not what I am suggesting, because then the entity would not be able to provide a common ground between the two networks. Instead, the element, be it an idea or a more physical entity, is connected to both the environment-network and the economy-network, thus providing a common node in the two networks. The node does not necessarily look the same when viewed in the economy-network as when viewed in the environment-network. For instance, will the understanding of emission quotas be different depending on whether the economic or the environmental characteristics are emphasised?

Staying with emission quotas, they also provide an example of how a less substantial idea can be used to avoid too great a change in production structures. Instead of trying to influence a lot of individual resources (facilities and products), emission quotas are used to reshuffle the production structure and thus focus on creating fewer emissions in total. From the perspective of the economy, it could therefore have been a good idea to introduce emission quotas for organic pollutants at an earlier stage. Instead of having to build and invest in a paint factory at Raufoss, Volvo could have bought emission quotas from RA and expanded their own facilities. However, the environment would have refused such a solution, as organic pollutants are coupled to local environmental impacts. This means that the specific site where emissions occur is of importance.

One of the basic ideas behind economising in business is cutting costs by employing fewer materials and/or less energy in production. This idea is clearly connected to the basic idea behind "environmentising", where less material and energy use aligns with less environmental impact. The hollow bumper beam is a good example of this, as all parties were pleased with the outcome in comparison to the earlier solid bumper beams. RA/Hydro achieved better margins as the price of the product decreased, Volvo could pay less, the owner of the car benefited from better fuel economy and the environment experienced fewer impacts.

5.4.2 Mediators between the economy and the environment

After having established that ideas must be partially material to be able to travel, it is time to look at the means employed to make them travel. In order to travel the routes between economy and environment shown in the previous sub-chapter, ideas from each of the network need vehicles (mediators).

The following text goes through a list of such mediators present in the case. The list is probably not exhaustive, but it lays the foundation for a better understanding of how different networks communicate. Whether the environment travels directly to the economy or via other network(s), the idea is that travel needs help to accomplish the transportation. Other networks are not seen as mediators themselves - an actor (in the ANT sense of the word) is always needed to do the logistical work. The vehicles must be part of networks themselves, but they are not necessarily the common nodes that are established through their mediation.

Test vehicles[133]

The importance of test vehicles in attracting new customers is unclear, but their importance as production experiments is undisputed. When introducing new models in the automotive industry, only small changes are made in the way they are produced when compared to previous models. The trend has been to change less and less in terms of materials, components and production technologies from one model to the next, as was shown in relation to platform development within Volvo. To explore different materials, components and production technologies, a small series of so-called test vehicles is produced. These vehicles are also used to highlight possible future avenues for a car producer in motor shows.

The development of bumpers in Volvo test vehicles has included the deliberate connection of industry and science. Although at first glance the causal direction has been to create industrial output from scientific input rather than to create scientific output from industrial input, the latter direction has also appeared as a consequence of the first. Industrial elements such as materials and processes are used as input in environmental science and test vehicles have provided analyses with new materials and processes whose environmental impacts can be compared with those already in use.

The realisation of the Light Component Project car showed possibilities both with regard to what was economically feasible and more environmentally friendly. Thus, test vehicles are special in being an arena in which elements suitable both for the economy and the environment are made, often simultaneously. One could say they function as guidance for future versions of both the economy and the environment.

Figure 5-6 below shows the transfer between the economy and the environment as mediated by a test vehicle with an environmental focus, such as the Light Component Project.

[133] It is only a funny coincidence that a vehicle is treated as a vehicle for translation.

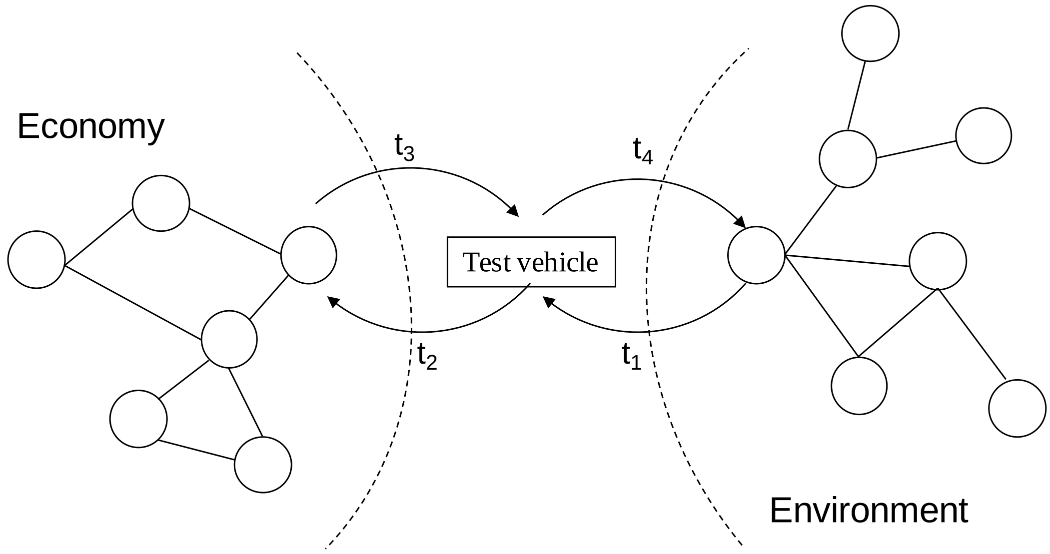

Figure 5-6 Test vehicles as vehicles for translation between the economy and the environment.

Figure 5-6 shows the test vehicle as an element produced and present in the economy and how it works to translate elements between the economy and the environment. In the initial phase of developing the test vehicle, it is nothing but an idea, a vision of something that can be driven. The first period (t1) involves collecting information from the environment. This information is compared with what is possible in the economy and translated into materials and processes during the second period (t2). One can say that the industrial processes, including not only activities but also actors and resources, are partially aligned to the environment. The third period (t3) is the actual production and testing of the test vehicle, where the industrial capability of testing the environmental ideas is put on trial. The fourth and last period (t4) concerns the transportation of information back to the environment. Here, materials and processes are once again translated into wording to fit articles, books and databases. The information may lead to additions, subtractions or substitutions in the actor-network that constitutes the environment. The test vehicles may therefore perform two simultaneous roles in relation to both networks. One is a "reality check", where industrial processes are compared to scientific descriptions. This happens in both directions. The second is the potential expansion of each network due to the importation of elements from the outside (i.e. the other network). The two initial stages of importing elements from the environment into the economy are quite limited in time and last for a short portion of the project period. The last stage of importing elements from the economy back to the environment is much less certain – indeed, there is no guarantee that this stage will ever take place.[134]

Test vehicles create the opportunity to translate knowledge from the environment into the economy and vice-versa. There is, however, a risk that the level of commitment may become lower in both networks. Although possibilities are displayed in each network, the actual connection between nodes may be too weak to bind the economy and the environment firmly together.

<u>Legislation</u>

Legislation provides a means to act at a distance. Actors in the economy are well aware of the legal framework in which they operate and although they may try to cheat, legislation always carry a risk of punishment. The text containing the legislation and the apparatus put in place to enforce this legislation ensure that elements are transferred from one network to another. However, the fact that legislation resides within a legal network also carries the threat that the environment will be distorted on the way, so that the environment will be coloured by the legal network to the extent that the environment is no longer visible.[135]

There are two instances in the case where legislation explicitly plays a part in connecting the economy and the environment. The first instance is the issuing of the bumper standard in the USA. Although the standard was not directly connected to the environment, it became important to introduce environmental arguments for the use of aluminium bumpers. This was because the standard forced manufacturers to increase the weight of bumpers in order to comply with legislative demands and car weight was already coupled with the environment through the issue of fuel consumption and associated emissions. As aluminium could be used to meet the standard without an excessive bumper weight increase, aluminium suddenly became environmentally friendly. More specifically, it led to a closer relationship between Volvo and RA and it expanded RA's customer base.

The second instance was the reduction in the limits of organic pollutants in Sweden. These limits were introduced in the discussion of the decision to set

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[134] Just as a test vehicle built for aims other than testing more environmentally friendly materials or technologies will only bring elements from the environment to the economy by pure luck.

[135] Only the route from environment to the economy is discussed, as this is the most often employed route. To the author's knowledge, and as explained earlier, there are few examples of the economy entering legislation that leads to an impact on the environment.

up a paint factory at Raufoss, rather than expanding facilities at Torslanda. Elements in the economy were changed, reflecting how legislation forced elements from the environment to make an impact. Furthermore, the harmonisation between Volvo and RA increased as a consequence of change in legislation.

The examples show the strength of legislation. It makes things happen to a greater degree than events that result simply from a knowledge of the environment. No new knowledge was introduced in any of the cases, that is to say that the environment was not changed, but the changes in legislation still led to actual restructuring in the economy. It is, however, disputable whether the changes were actually in a more environmentally friendly direction.

Figure 5-7 shows how legislation participates in the process of transferring elements from the environment to the economy.

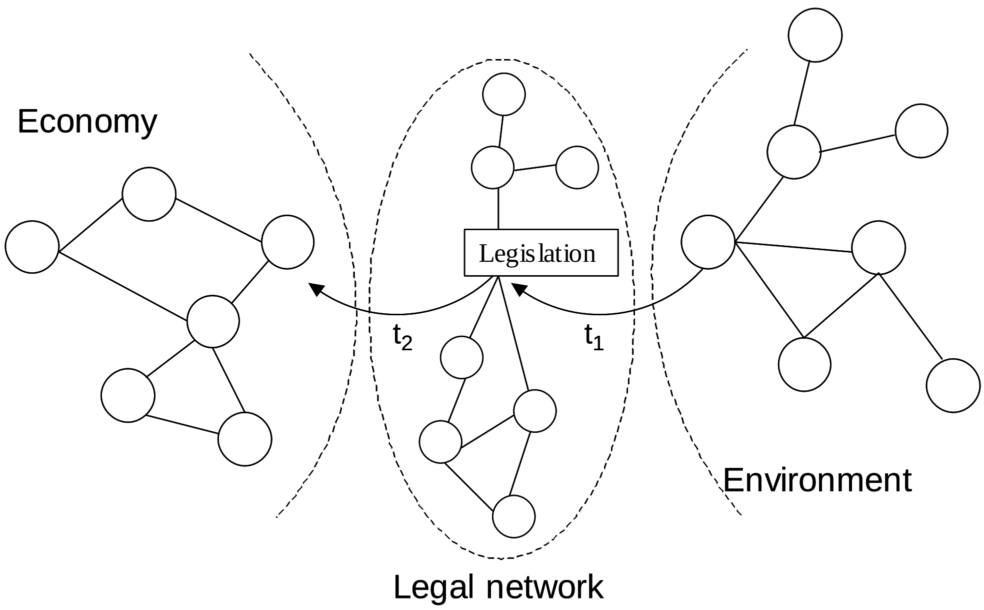

Figure 5-7 Legislation working as a vehicle for translation for transferring elements from the environment to the economy.

At t1, elements from the environment are disconnected from several of the nodes in which they are in contact with in the environment, and they are brought into a legislative text. New connections are established with elements in the legal network, such as threats of fines and a control apparatus to check legal compliance. At t2, the elements from the environment, together with the legal elements, are brought into the economy to establish connections between elements in the economy, the legal network and the environment.

Neither the economy nor the environment is in control of which elements are transferred and/or the time at which the transfer occurs. The prioritising of elements to be included in environmental laws is not in the hands of the scientists producing the environment (although some are participating in defining acceptable levels of emissions, for example), but rather in a combination of other networks such as the media network or the public network (including e.g. NGOs).

The consequences of using legislation as a vehicle for translation may be that neither the environment nor the economy ends up feeling that their needs are heard. In fact the case is the opposite: the economy may develop an image of a troublesome environment that forces the economy to reorganise without any gains, whilst the environment does not establish sufficient or sufficiently strong bonds to nodes in the economy to get an impression of a real impact. In other words, the economy appears to only answer to legislation and not to real environmental needs.

Non-governmental organisations (NGOs)

NGOs are interest organisations that work to further a cause in a basically idealistic fashion. At least that is how they appeared a few decades ago. Since then, the larger NGOs, such as Greenpeace, have become more and more professionalised. The focus here is on NGOs involved with the environment.

Just as in Håkansson and Waluszewski (2002) where the Swedish furniture producer IKEA uses a relationship with the environmental NGO Greenpeace to make a recognised standard for recycled paper, Volvo invited Greenpeace to its production facilities at the beginning of the 1980s. In both examples, Greenpeace is seen as a carrier of the environment and is allowed to directly influence business practices, although the ideas Greenpeace bring to the company may be altered or never actually materialise in the production. Pehr Gyllenhammar explained his and Volvo's involvement with Greenpeace like this:

> "I saw engagement between business and NGOs as a vital step in furthering understanding between both parties and in plotting a more responsible path for Volvo itself…[This] engagement was repeated in the later 1970s, when we were subject to a challenge from Greenpeace. The story provides a useful example of how things can go well, of how the energies of confrontation can be harnessed to produce a positive

> outcome for all parties. On the one hand, Greenpeace had identified the automotive industry as a primary source of environmental degradation. It did not know, but it suspected that our production processes violated the environment. In Volvo, we were concerned to deliver a first class product, which met the vital societal need for personal travel. We were concerned that all aspects of our business should be conducted to the highest standards. We already had an environmental policy, which was in full operation. It targeted us to seek to avoid waste, to avoid pollution and to promote the highest levels of safety both in our factories and in our products…[It] seemed to me to be wholly sensible to invite Greenpeace into our business, for them to take a good look around and for us both to have an exchange of views. I saw that we could learn from their concerns in our quest for ever better production and products with reduced impacts on the environment and they could learn from us about the practicalities of the automotive industry in the hands of a concerned producer…[It] was a fruitful exchange. We did not trade insults from entrenched positions. We listened to one another and profited from one another. This successful example of engagement has now subsequently been replicated many times over in subsequent relations between NGOs and business."[136]

Gyllenhammar actually explains the transfer that may occur. The statement "Greenpeace could learn from us about the practicalities of the automotive industry in the hands of a concerned producer" carries the implicit meaning that Greenpeace would carry such information back to the environment.

Greenpeace was also instrumental when revealing the different views of Ford and Volvo in relation to the Kyoto protocol in 2001 (Anonymous 2001). Volvo had explicitly supported the Kyoto protocol during the 1990s, whereas Ford was reluctant to accept the protocol, apparently on the grounds that developing countries did not have to take their share of emission reductions. This difference in stance did not pose a problem until Ford acquired Volvo in 1999. However, when a Greenpeace journalist made a Volvo spokesperson reveal that their position was the same in 2001 as in the 1990s, hectic activity took place in the two organisations to achieve a consistent position. It could have been a risky game, one in which Volvo would have had to adjust their proactive role in terms of the environment but, instead, Ford adjusted its position and came closer to Volvo's.

Although it may be questionable whether NGOs are actually part of the environment when the environment is characterised as scientifically driven, the assumption here is that NGOs are carriers of the environment as produced by science. Most NGOs use the environment produced by science to further the issues that they are championing. That said, they rarely

[136] Excerpt from Pehr Gyllenhammar's Gothenburg speech

participate in producing scientific outputs and use other channels – or networks if you like – such as mass media for the purpose. This does not mean, however, that their output is irrelevant to environmental science. Public opinion and engagement are important in establishing which scientific projects are granted funds and attract scientists (whatever comes first). Another point connected to this is that NGOs carry the threat, much like legislation, of another network acting upon the economy. The companies may feel a real threat through the NGOs connecting the company (an element in the economy) to an element from the environment such as a harmful substance and leading the media network to create negative publicity for the company. Once again, this may lead to a decrease in sales or negative attention from authorities.

Figure 5-8 shows how the NGO functions as a vehicle for translation between the networks.

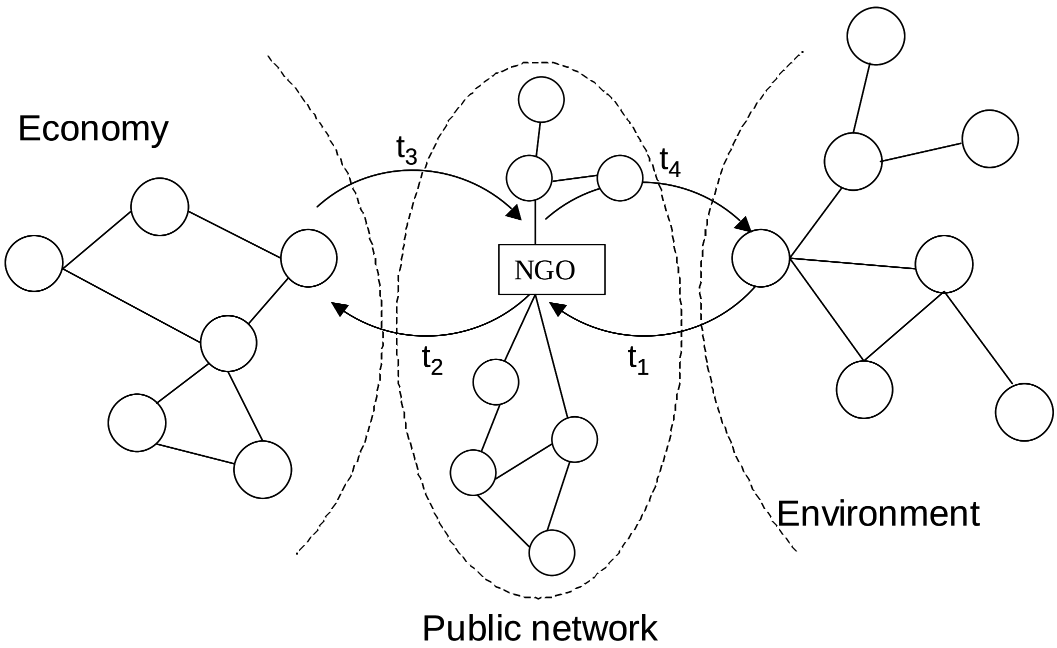

Figure 5-8 Displaying how an NGO works as a vehicle for translation for transferring elements between the economy and the environment.

NGOs pick elements from the environment at t_1, which are transferred to the economy at t_2. The delay between these two stages may be substantial, as the latter requires the NGO to approach or be approached by a company (if the NGO does not include the extra step of going through a newspaper or another media channel to push the element into the economy). If the company actually involves itself in a dialogue with the NGO (as Volvo did), knowledge about industrial processes is transferred to the NGO at t_3. This knowledge (i.e. these elements from the economy) may again find its way to the environment at t_4, given that the NGO communicates with the scientific community involved in producing the environment. In a similar way to the test vehicle example, NGOs appear to be much more efficient in getting elements from the environment into the economy than getting elements from the economy in the opposite direction.

The above quote from Gyllenhammar also shows that engaged individuals have an important role in mediation – remembering that NGOs normally consist of a number of engaged individuals. Without Pehr Gyllenhammar inviting an NGO inside the gates of the factory, the economy and the environment would still be in opposition.

Engaged individuals

Both the economy and the environment are inhabited by numerous individuals that participate in defining what the networks are and are not. Some of these individuals may be instrumental in creating connections between different networks and it is this engagement that is emphasised here.

The first engaged individual we met was *Pehr Gyllenhammar*, who stated Volvo's environmental policy at the UN meeting in Stockholm in 1972. By so doing, he committed the company to including environment in its operations and provided the possibility of including environment as one of Volvo's core values. He is recognised as being the key figure in establishing a concern for nature in Volvo. Even his ideas about organisation of the work environment are now starting to be translated into environment, as damages to human health from the work environment are making their way into LCA and environmental assessments. One of the physical imprints left by Gyllenhammar was the Kalmar factory, where Volvo has tried to reverse the belief in the conveyor belt and instead create workstations where the same people are responsible for assembling almost an entire car. Parallel to his commitment to the environment, he has been the brain behind several of Volvo's investment projects during his time as CEO of the company.

We have also met *Rolf Marstrander* in Hydro Aluminium, who participated in the set-up of the industrial ecology programme at NTNU. He has brought the concept of industrial ecology into Hydro, as well as financial resources into environmental science.

In addition, there are numerous nameless individuals who, through their engagement, have participated in bringing elements from the environment to the economy. This does not exclude elements going in the other direction. Contact between individuals in business organisations and scientists leads to information from the economy being included in the environment. Baumann (1998) studied the use of LCA in industry and emphasised the role of the "LCA entrepreneur" in introducing and spreading such a tool in companies. Employees in the environmental department in Volvo were instrumental in starting to employ LCA as a tool in the company and also encouraging participation in research about the EPS system.

Although the thesis itself has downplayed the role of the individual actors, as both underlying theories (IMP and ANT) have emphasised the importance of other actors (in ANT terminology) or activities and resources (in IMP terminology), this does not discount the potential for human beings to create bonds between nodes. IMP and ANT are reacting to theories that locate all the abilities to create stability or change in human actors while disregarding other matter. In fact, the theories and this thesis recognise that human individuals are often necessary agents to direct elements and therefore connect nodes.

One of the dangers to companies and perhaps to the environment is that engaged individuals may leave the organisation. Much of the environmental knowledge is often associated with a single person and it disappears when that person disappears, making individuals volatile vehicles of translation. Thus, although individuals may be good at making elements from the environment travel to the economy, companies must use other means to tie the elements to other existing elements in the economy in order to make the connections last.

Figure 5-9 shows how engaged individuals participate in transferring elements between the networks.

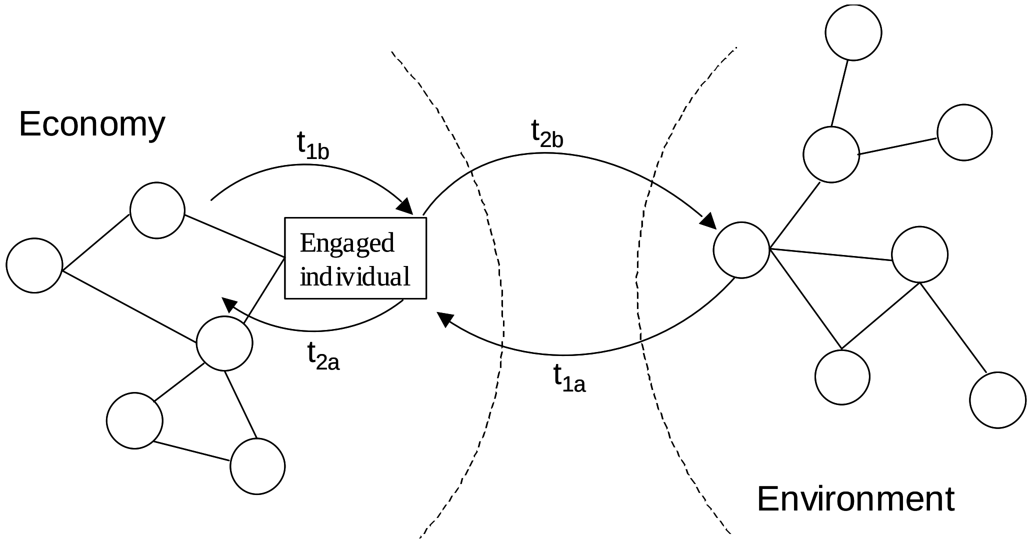

Figure 5-9 An engaged individual functioning as a vehicle for translation for transferring elements between the economy and the environment.

Figure 5-9 has a different numbering of the stages than the preceding figures displaying vehicles for translation. This is because engaged individuals are able to choose the direction of travelling to a larger degree. He or she may either pick up an element from the environment at t_{1a} and bring it to the economy at t_{2a} or pick up an element from the economy at t_{1b} and bring it to the environment at t_{2b}.

Although the figure shows an engaged individual within the economy – as most individuals described in the preceding text were residing there – the individuals may also be part of the environment or another network. The position of the individual has consequences for the means that he or she can employ to undertake the transference, the order of the stages (i.e. whether the economy or the environment is approached first) and the ability to connect the travelling elements to other elements at the final destination.

Environmental management tools

Environmental management tools encompass all the technologies involved in environmental management, such as standards and different documents, and thus cover some of the instruments employed by the environmental departments. Examples include the ISO 14000 series, EMAS, supplier evaluation schemes and the method of LCA.

The management tools are constructed with the aid of vehicles of translation, for instance the International Standards Organisation (ISO). This process of creation was briefly touched upon in the description of the Environment*, as science is an important contributor of input. Here, however, the emphasis is on how the ready-made environmental management tools residing in the economy function as vehicles themselves.

ISO 14001 and EMAS are environmental management systems that provide a framework for companies to document environmental figures such as resource use, waste generation and emissions. In the process of documenting the figures, the elements from the environment become connected to the industrial process and thus become elements from the economy. In a similar way to legislation, this means that the tools have an ability to bring elements from the environment with a certain force behind them. The force is less than for legislation, as the regime connected to document compliance carries a lesser threat of negative consequences than the legal network. However, the positive effect of this is that the introduced elements may be viewed as something the company *wants* to work with rather than something it *has* to comply with.

Provided that they include similar environmental elements to the aforementioned management systems, supplier evaluation schemes have a similar effect in forcing suppliers to incorporate those elements in their operations.

There is a danger associated with both standards and evaluation schemes that the elements from the environment may become disconnected in the process, losing their links to the environment and becoming merely figures reported from production.

LCA is a different story, with the method's close association to the environment as produced by science. While companies have a tendency to declare: "Yes, we are certified" when it comes to ISO 14001 and EMAS without any further specification, LCA is used to produce and communicate actual environmental figures. LCA has the ability to bring a large number of elements from the environment to the economy and simultaneously to ensure that the links to the environment are in place. Close links back to the environment even make it possible to bring elements from the economy (e.g. specific production processes and products) back to the environment. LCA may therefore seem like a perfect vehicle for translation, but the complexity of the method (i.e. the large number of elements and the inherent need for specific knowledge of both the environment and the economy) means that it is not easily accessible for most actors. This complexity can reach absurd levels when the output from the tool always ends up with the single conclusion – due to the almost sole focus on climate change – that the emission of climate gases must be reduced. The last point has led Volvo to reduce its use of LCA because of this issue.

Figure 5-10 shows the stages involved when environmental management tools are employed as vehicles for translation for transferring elements from the environment to the economy.

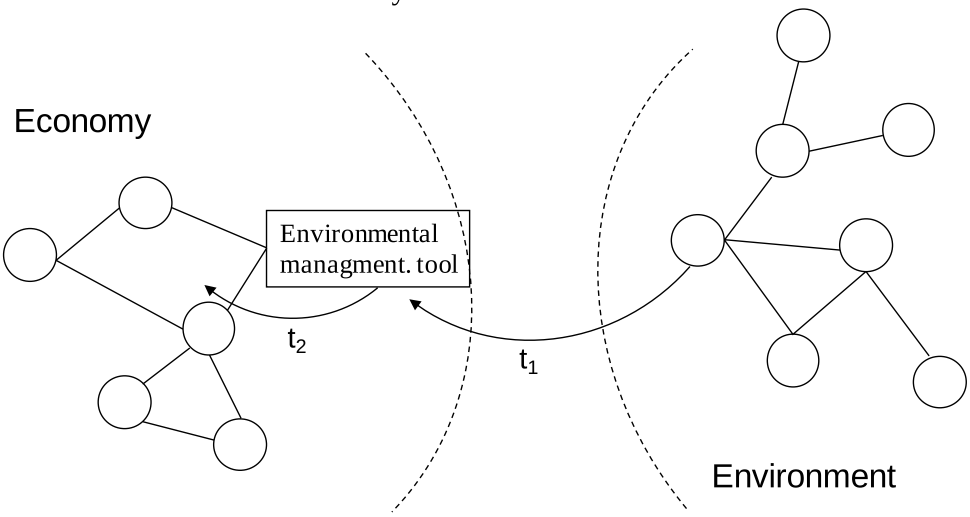

Figure 5-10 An environmental management tool working as a vehicle for translation for transferring elements from the environment to the economy.

The diagram shows how environmental management tools include elements from the environment at t_1. When employed in a company at t_2, the elements are connected to the daily operations of the company and therefore to the economy. In the earlier text, references were made to how the application of LCA may make it possible to bring elements from the economy back to the environment. However, this route is not shown in the diagram, as it demands other vehicles of translation for travel. Performing an LCA internally in a company does not lead to expansion or specification of the environment if the results are not transferred to the environment in forms such as numbers in a database or journal articles.

Reports

The reports referred to here are reports published by business organisations, e.g. annual reports, environmental reports and sales brochures. This means that the vehicles of translation examined here mostly work as mediators from the environment to the economy, as textual output from business organisations is mainly directed towards the economy.

Starting in the mid-1990s, both Volvo and Hydro included environmental figures alongside the economic figures in their annual reports. Hydro introduced the concept of eco-efficiency in 1998 and started reporting it in 1999, based on emissions or resource use divided by the economic value of product. The reporting changed again in 2001, using product volume as the volume indicator. The report includes graphs that are measures of environmental elements mixed with measures of elements from the economy. Eco-efficiency measures such as greenhouse gas emissions per ton of product place environmental data on top of economic data. The fraction line provides an interface between the elements from the two networks and the resulting figure is actually connecting one or more nodes in the environment with one or more nodes in the economy. The question that this poses is whether and how these connected nodes manage to remain connected to other nodes in the networks. The resulting hybrids of the economy and the environment may be too unfamiliar to be approved by any of the networks.

In 2003, Hydro's environmental figures were put into a separate environmental report, allegedly to promote greater attention. However, the risk with an environmental report is that it might not seem connected to the economy - so whilst the aim is to give the environment enhanced status, it may instead be ignored.

On the way from environmental reports to sales brochures, elements from the environment become more and more stereotyped, and thus more and more likely to be removed from the original connections in the environment. At the same time, sales brochures may be closer to the "pure" economy – to the original focus on exchange – and thus better connected to elements present in the economy than an environmental report. There seems to be a trade-off between keeping connections to elements in the environment and ensuring that connections to elements in the economy are made.

An environmental product declaration (EPD) is a mixture of an environmental report and a sales brochure. Based on data from LCA and a standard format for presentation, the EPD is supposed to give objective environmental information about a product to a potential purchaser. Volvo first employed EPDs as early as 1995. Although the EPD does not contain commercial information, the standard format for simple presentations of environmental figures makes it possible to include elements from the environment in purchasing decisions. The requirement of an LCA underlying the presented results ensures that links to the environment are kept intact.

Figure 5-11 shows how reports functions as vehicles for translation between the networks.

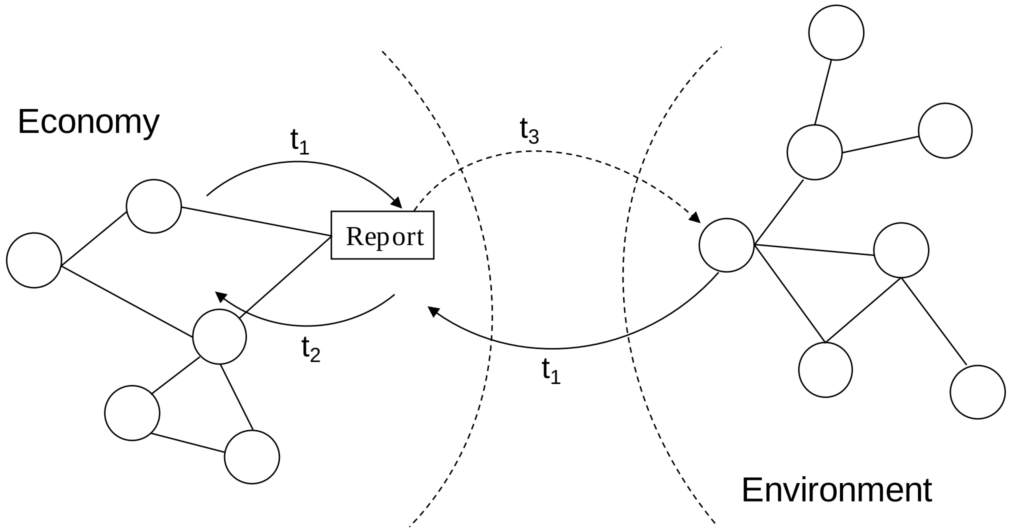

Figure 5-11 A report works as a vehicle for translation for elements between the economy and the environment

The diagram shows that elements from the environment (as well as elements from the economy) are included in a report at the first stage (t_1). At the next stage (t_2), the elements from the environment are allowed to impact on other elements in the economy. However, there is no guarantee that this will happen. Reports are lasting and the connections that are made between elements will be in print for years, but reports may bring less commitment and can easily be left on the shelf. It is also possible that the report will be taken up by scientists producing the environment (shown as the dotted line happening at stage t_3), and that the elements from the economy therein will be connected to other elements in the environment.

<u>Environmental departments</u>
This category of vehicles for translation may immediately look like an expansion of former categories. Isn't an environmental department just a larger group of engaged individuals? Such a suspicion is further emphasised by the inclusion of people from environmental departments in the former category. However, an argument can be made for considering environmental departments as being a different creature – a different vehicle for translation – from the engaged individuals. Part of the reason for this is that the instruments with which the environmental department is equipped (such as environmental management tools) represent a place in the organisational

hierarchy and channels for reports. Environmental departments can thus be viewed as an assembly of other vehicles of translation or a vehicle-network, where the combination of elements creates something different from what can be created by the individual vehicles within the department.

Environmental departments are more or less deliberately set up to be mediators between the environment and the economy. Related closely to industrial production, they are instrumental in providing necessary information for making environmental decisions. They also work to translate industrial production into environmental figures for outward communication. They are therefore expected to bring elements from the environment into the economy in relation to production and products and to bring elements from the economy to the environment via conferences and journal articles (often in cooperation with scientists at universities).[137]

Volvo has reorganised and decentralised environmental responsibilities on several occasions. For example, they have used internally focused environmental departments to take care of elements from the environment connected to factories and processes, while using externally focused environmental departments to handle elements from the environment associated with products. Attempts at decentralising can be looked upon as attempts to ensure that every employee is an engaged individual, making the company fully equipped with human vehicles for translation. However, the ability to function effectively as vehicles for translation may be severed if connections to the environment are missing due to individuals not having access to appropriate technologies (i.e. environmental management tools) or nodes in the environment. The strength of the central environmental department lies exactly in the combination of elements that produces trustworthiness in both networks.

The position of the environmental department within the economy, but with responsibility for elements from the environment, creates both possibilities and hindrances: possibilities because it is clearly allowed and even expected to bring elements from the environment into the economy and because when bringing elements to the environment, they will almost certainly retain connections to elements in the economy; hindrances, because the environmental mandate may lead to it being overlooked by elements in the economy and the placement in the economy may lead elements in the environment not to acknowledge the elements it brings.

[137] The environmental department is also expected to be the contact point in communication with environmental authorities, thus keeping connections to nodes in other networks that are also linked to the environment.

Figure 5-12 shows how an environmental department contributes as a vehicle for translation for transferring elements between the economy and the environment.

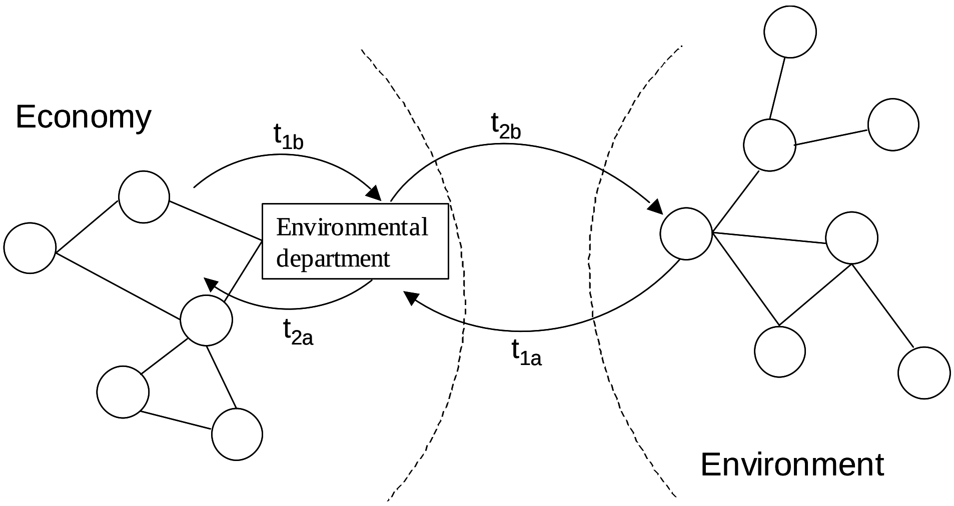

Figure 5-12 An environmental department functioning as a vehicle for translation for transferring elements between the economy and the environment.

Figure 5-12 resembles Figure 5-9, as it shows the role of engaged individuals as vehicles for translation, in that environmental departments can also choose which direction they will support in transferring elements. Either an element from the economy can be taken up by the environmental department (at t_{1b}) and transferred to the environment (at t_{2b}), or the environmental department can pick up an element from the environment (at t_{1a}) and transfer it to the economy (at t_{2a}). One of the reasons why both engaged individuals and environmental departments are free to choose their direction is their continuing presence as vehicles for translation. This contrast with elements such as test vehicles or NGOs, which are only physically present in conjunction with the economy for short time periods (although the elements they have transferred may make a continuous impact).

Thanks to their "heavier" connections to other physical entities, environmental departments are less volatile vehicles of translation than individuals, but their actual ability to mediate the transfer of elements is dependent on the structure and routines provided for contact between the environmental department and nodes inside and outside the economy.

Research institutions

Volvo and Hydro (and earlier RA) have always had close contact with research institutions, especially in order to advance production technologies. Typically in the Nordic countries, research is often carried out in universities and research institutions with sponsorship from companies, rather than being performed in the companies themselves. In terms of environmental matter, we have already encountered scientists from Chalmers University involved in developing the EPS system. We have also seen the close links between Hydro and the industrial ecology programme at the Norwegian University of Science and Technology (NTNU).

Research institutions function in almost the same way as legislation, providing the economy with elements from the environment. The advantage compared to legislation is that the elements may travel in a more "pure" form, without connecting elements from any other network to those from the environment. That is also the main disadvantage. The elements travel to the economy without much commitment in connecting them to elements already present in the economy. The transferred elements may end up unused, isolated and forgotten. Thus, research institutions are efficient in transporting elements from one network to another, but perhaps not as efficient in ensuring that the elements remain held in place.

However, unlike legislation, research institutions are also capable of carrying elements from the economy to the environment. Real production technologies and processes are carried back to the environment and connected to relevant elements. However, research institutions are not necessarily the ones initiating this transfer. For example, engaged individuals or environmental departments in the economy may employ research institutions as writing partners in transferring elements from the economy to the environment.

Figure 5-13 shows how a research institution works as a vehicle for translation for transferring elements between the economy and the environment.

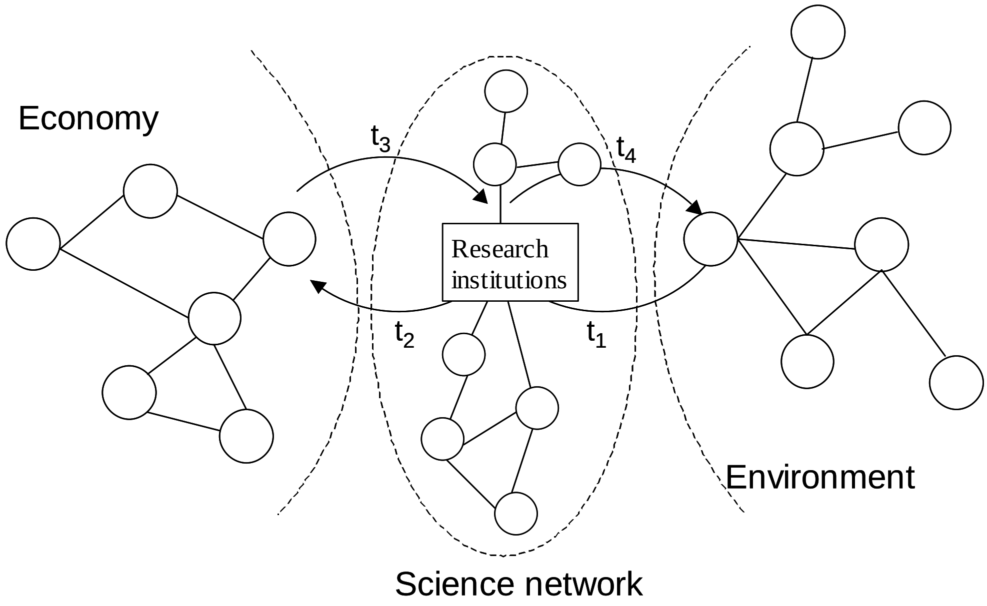

Figure 5-13 A research institution working as a vehicle for translation between the economy and the environment.

The diagram demonstrates how a research institution resembles an NGO in terms of the stages involved in transferring elements between the economy and the environment. Elements from the environment are taken up at t_1 and introduced to the economy at t_2. When in contact with companies, research institutions pick up elements from the economy at t_3, which are transferred to the environment at t_4. In contrast to Figure 5-8 showing NGOs, the line denoting the stage at t_4 is not dotted, as research institutions with scientists involved in the production of the environment are expected to transfer elements to the environment.

There may be several examples where the stage at t_2 is bypassed, where research institutions approach business organisations to collect elements from the economy and insert these into the environment without leaving any elements from the environment behind in the economy.

Computer software

As shown in the descriptions of both the Economy* and the Environment*, computers and computer software have played an instrumental role in developments during the last decades. The ability to store and combine large amounts of information has had a great impact on automotive design, supplier handling, climate models and LCA, to name but a few examples.

Each of these fields has developed as the result of simpler access to historical information compared to that of a printed archive, greater accuracy when performing drawings or calculation compared to a piece of paper and the ability to perform a larger amount of calculations simultaneously. In addition to software participation in the development of specific fields, it also makes it possible to put elements from the economy and the environment together and make them influence each other, e.g. using design tools or in Internet publishing.

A wide variety of different computer software is involved in the construction of a car. Simulations of the different characteristics (e.g. weight, costs, resource input and crash characteristics) of the different components of the car are all communicated to a software programme, ensuring that the desired design of the car remains possible. Elements from the environment are thus introduced alongside other elements in the making of a car. There is, however, no guarantee that the environmental elements are actually given any weight in the decision between different alternatives for components. In fact, there is a larger propensity for focusing on the elements more closely connected to the economy, such as costs and functional characteristics. If a decision based on these characteristics also carries more and/or heavier connection to elements from the environment, it is often pure luck.[138]

Internet publication of elements from the economy and the environment offers the chance of an increased spread, but it is perhaps more questionable how strongly it ties Volvo and Hydro to any environmental obligations. The user of the web page is granted access to environmental information and it is placed on the same level in the hierarchy as financial data, a company presentation etc. Thus, on one hand, the Internet publication does not discriminate between elements from the economy and from the environment. On the other hand, there is no commitment and no obligations that force any user to actually look at them. This means that connections to other nodes in either the economy or the environment may be weak.

Figure 5-14 displays the process of transferring elements between the economy and the environment with computer software acting as a vehicle for translation.

[138] This assumes that more entanglement between the economy and the environment is for the good (this being the underlying premise of this thesis).

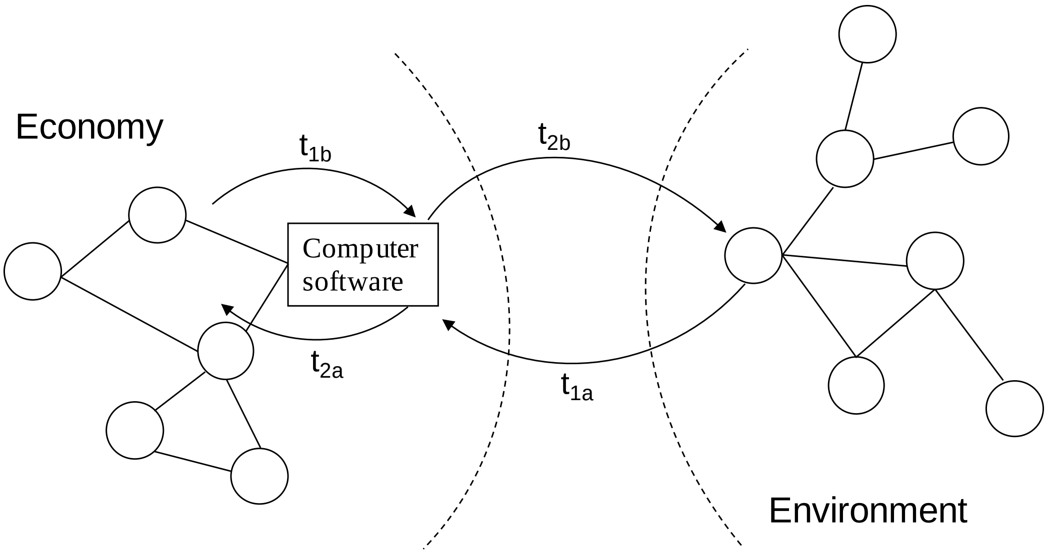

Figure 5-14 Computer software working as a vehicle for translation for transferring elements between the economy and the environment.

The diagram shows how computer software is able to pick up elements from the environment at t_{1a} and transfer them to the economy at $t_{2a;}$ or to pick up elements from the economy at t_{1b} and transfer them to the environment at t_{2b} in the same way as engaged individuals and environmental departments. Computer software can also reside in all networks, in the same way as engaged individuals. Placement within the economy in Figure 5-14 is shown in this way because the computer software described in the preceding text is placed there.

5.4.3 A summary of vehicles for translation

The transfer of elements between the economy and the environment (in either direction) is accommodated by mediators referred to as 'vehicles for translation'. Some of their important characteristics are summarised in Table 5-2.

Table 5-2 Characteristics of different vehicles of translation

Vehicles for translation	Residing in network	Travel routes employed	Strengths	Weaknesses
Test vehicles	Economy	Directly from environment to economy, and directly from economy to environment	Creates opportunities to explore the economy of environmental improvements	Does not carry much commitment, the information is partly sealed
Laws and regulations	Legal	To economy from environment via other network and possibly the opposite route	Has the potential to put pressure behind the transfer	May alter the entity into a legal form and miss important actors from the environment
NGOs	Public	Directly from environment to economy	Can quickly respond to changes in the environment or economy because of loose couplings	Carries less weight because of loose couplings.
Engaged individuals	All*	All	Large potential in connecting nodes	Connections leave if individual leaves
Environmental management tools	Economy	From environment to economy and possibly the opposite	Great amount of connections and suitable for the economy	Can lose sight of the environment
Environmental departments	Economy	All	Great amount of connections and suitable for the economy	Can lose sight of the environment
Research institutions	Science (and Economy)	From environment to economy and from economy to environment	Efficient in transferring elements	No commitments involved
Reports	Economy	From economy to environment and possibly the opposite	Creates lasting connections between elements	Can easily be overlooked and left on the shelf
Computer software	All	All	Makes connection between elements easily	No commitments involved

* Although we have only met people from industry, i.e. the economy, here

From Table 5-2 it becomes evident that none of the presented vehicles for translation represents only advantages (or disadvantages for that matter).

Those that are most efficient in transferring elements seem to carry the risk of disconnecting the elements from the original network, while those that are most efficient in securing connections to nodes in the two networks seem to be slow-moving and inefficient in the transfer process.

All the vehicles presented here seem much more directed towards and efficient in transferring elements from the environment to the economy than along the reverse route. This may stem from having used an industrial product as the tool to produce knowledge about the two networks. The focal element is residing in the economy and much more connected to what happens in the economy-network than in the environment-network. Thus, important vehicles for translation for travelling the opposite route may have been overlooked. It is also possible that existing vehicles for translation are more interested in transferring elements from the environment to the economy than vice versa.

There are few elements acting as a direct response to the environment, i.e. nodes (or actors) in the environment forcing themselves or other elements in the environment to travel. Efficient vehicles for translation – those that manage to bring elements across to the economy and make them stay – carry with them the threat of another network acting on the economy, such as the legal network or the media network. Perhaps nature itself is too far away for any company to see the value in acting on its behalf. Perhaps the environment has been too effective in translating nature into graphs and numbers for anyone to smell the stench of pollution or sense the water rise. Thus, the vehicles such as legislation and NGOs that are most efficient in mediating travel for elements from the environment to the economy are also those with the highest risk of disconnecting the elements they carry from the environment itself.

The different vehicles for translation have different longevity in the networks. Some (e.g. engaged individuals and environmental departments) are physically present and ready to transfer elements for long time periods, while other (e.g. test vehicles) are only present for shorter periods of time. This does not mean that the elements the test vehicles transport are short-lived - they may stay in the networks for much longer than any individual or department. However, the test vehicle after completion cannot adapt to accommodate changes in the networks as individuals or departments can.

Although the vehicles have been presented one after the other, it will also be obvious that often more than one appears simultaneously. In fact, in accordance with the basic networking mode in ANT, there is probably a need for more than one vehicle to make an impact. For instance, a test vehicle needs engaged individuals in order to be created with a concern for the environment. Furthermore, it needs reports to document the relevant environmental issues and these reports may require an environmental department or a research institution in order to be written.

The list of mediators and the connection to the ideas they carry underline the fact that it may be difficult to differentiate between the ideas themselves and the means used to transport them. Rather than being a problem of separation, this can be understood as an opportunity for the involved ideas and mediators to mutually influence each other. The substantial ideas and the mediators that let them travel become mixed to such an extent that it can be hard to sort one from the other.

The vehicles of translation may be seen as hybrid constructions consisting of material from both the economy and the environment. To be effective in the logistics involved in getting ideas from one to another, they must be able to communicate in both networks. The word 'logistics' encompasses more than just transport when used in a business process sense, i.e. the inclusion of activities involved in facilitating transport and storage. In a similar way in this example, the mediators cannot only be involved in transporting substantial ideas from one to the other. They must also be effective in enabling the usage of that which is transported in the respective network. As an example, consider boat transport: it is not sufficient just to have a boat to make transport by ship effective. Many physical installations – such as quays, cranes and containers - and organisational "installations" such as schemes and operating procedures are necessary accompaniments. The same goes for the mediators; they must be like a ship, but also include the surrounding infrastructure (cranes, quays etc.) that makes the substantial ideas able to travel from within one network to within another.

This means that the vehicles for translation must be flexible in order to move between the two (and perhaps other adjacent) networks, yet the flexibility must not be so extensive that the vehicle is no longer fit to connect to nodes in the networks.

6. Conclusion

The main aim of this thesis was to find out about the relationship between the economy and the environment. The starting point was the apparent conflict between these two networks in public discourse. In order to create a manageable study, descriptions of the two networks were produced by focusing on aluminium bumpers delivered to Volvo from Raufoss.

One important assumption for describing the economy was that its production is closely connected to industry. The industrial network approach (IMP) was applied to sort out important elements in the economy network connected to bumpers (referred to as the Economy* within the thesis) from 1970 to 2006.

A similarly important assumption concerning the environment is that its production is closely connected to science and thus that the images we have of nature are to a large degree produced by natural sciences. The actor-network theory (ANT) was applied to sort out important elements in the environment network connected to aluminium bumpers (referred to as the Environment* within the thesis) from 1970 to 2006.

The elements from each of the descriptions were placed together in an analysis in order to find shared elements that could provide real interfaces between the economy and the environment. I then specified the four different routes that the elements can travel along and described the means to make them travel.

6.1 Summary of main findings

In order to summarise the main findings, it would be useful to return to the research questions posed at the beginning of the thesis. These are:

- What elements are common in the Economy* and the Environment*?
- How did these elements become common?

Answering the questions requires insights into the elements of each of the networks and how they have evolved. The process of capturing these has resulted in knowledge of each of the networks as well, but before presenting these, let us see what the thesis tells us about the relationship between the economy and the environment.

6.1.1 The relationship between the economy and the environment

The descriptions of the economy and the environment revealed that the emphasis of each coincides only to a very small degree, thus it can stated that:

> *There are few common elements in the economy and the environment.*

This finding may have been both trivial and expected. However, it may explain why the relationship between the economy and the environment is often portrayed as a conflict in public discourse.

Some basic elements are shared. Elements from nature are used as raw materials in the economy and simultaneously constitute the elements that the environment is to protect. Usage of the elements is thus frequently connected to different – often opposite – ideas in the economy and the environment.

There are, however, elements to be found with similar characteristics in both networks, such as ideas about trading and quotas. A connection between the economy and the environment requires the sharing of elements, as it is only through common nodes that networks can be connected. These elements become shared by travelling from one network to the other and connecting to nodes in the latter without losing connections to nodes in the former. The next section will describe such travel routes.

Travel routes

In order to understand how elements are transferred from one network to the other, four possible travel routes between the economy and the environment were examined, showing that:

> *Elements can be transferred from one network to the other through both direct and indirect routes.*

The routes and some of their important characteristics are presented in Table 6.1.

Table 6-1 Travel routes for elements being transferred between the economy and the environment

		Example	Consequence
Direct	Environment – Economy	LCA imported into the economy directly from research institutions.	Elements are transferred in original state, retains connections in the environment while being present in the economy. Small incentives for creating strong bonds to nodes in the economy.
	Economy – Environment	Materials, production technologies and philosophies imported into the environment from articles or reports.	Defines what elements the elements in the environment are related to (e.g. what industrial processes that needs to be assessed). Accusation of false claims if the connections to elements in the environment are too weak.
Indirect	Environment – Economy	Environmental element brought into legislation. Legislation enforced in economy.	Binds elements from the environment to elements already present in the economy. Elements from the environment are connected to elements from other networks and may change character. Increased pressure in connecting.
	Economy – Environment	Emissions trading included in climate change after commodifying CO_2	The original element from the economy may be distorted, creating a stereotypical view of economy in other networks. May hamper the connections from stressors to consequences in the environment.

As seen in Table 6.1, the presented routes were direct and indirect routes from the economy to the environment and from the environment to the economy. Travelling along a direct or an indirect route creates different consequences for how the elements are perceived upon arrival and also for what connections the elements carry. The networks are therefore affected by how the transfer occurs. Indirect routes lead to a greater risk of altering the original element as it becomes connected to elements in the network(s) it travels through. However, it is also more likely that the element will actually connect at the final destination because the extra nodes connected to the element give more weight.

The words 'direct' and 'indirect' may bring connotations of one being simpler and faster than the other. However, there is no reason to suspect that going directly from one network to the other is easier than travelling along an indirect route. The important factor is how easily the element can be assimilated in the network to which it is travelling. A detour to another network may therefore make the transfer both faster and easier.

Elements do not normally travel by themselves, but often require the aid of mediators – vehicles for translation – to be transferred from one network to the other. Examples of such vehicles for translation are presented in the next section.

Vehicles for translation

When travelling both direct and indirect routes, the elements that are transferred from one network to the other are assisted through being connected to other elements - vehicles for translation – that are able to travel. These vehicles for translation exist in a number of different shapes, thus:

> *Those elements that accommodate transferring between networks (i.e. vehicles of translation) are heterogeneous.*

To better understand what this means and what consequences it has, a list of the vehicles for translation examined in the thesis and some of their important characteristics are provided in Table 6-2.

Table 6-2 Vehicles for translation for transferring elements between the economy and the environment.

Vehicles for translation	Residing in network	Travel routes employed	Strengths	Weaknesses
Test vehicles	Economy	Directly from environment to economy, and directly from economy to environment	Creates opportunities to explore the economy of environmental improvements	Does not carry much commitment, the information is partly sealed
Laws and regulations	Legal	To economy from environment via other network and possibly the opposite route	Has the potential to put pressure behind the transferring	May alter the entity into a legal form and miss important actors from the environment
NGOs	Public	Directly from environment to economy	Can quickly respond to changes in the environment or economy because of loose couplings	Carry less weight because of loose couplings.
Engaged individuals	All*	All	Large potential in connecting nodes	Connections leave if individual leaves
Environmental management tools	Economy	From environment to economy and possibly the opposite	Great amount of connections and suitable for the economy	Can lose sight of the environment
Environmental departments	Economy	All	Great amount of connections and suitable for the economy	Can lose sight of the environment
Research institutions	Science (and Economy)	From environment to economy and from economy to environment	Efficient in transferring elements	No commitments involved
Reports	Economy	From economy to environment and possibly the opposite	Creates lasting connections between elements	Can easily be overlooked and left on the shelf
Computer software	All	All	Makes connection between elements easily	No commitments involved

Table 6-2 shows the vehicles for translation examined in the thesis and their advantages and disadvantages. Those that are most efficient in transferring elements seems to carry the risk of disconnecting the elements from the original network, while those that are most efficient in securing connections to nodes in the two networks seems to be slow-moving and inefficient in the transferring process.

The different vehicles for translation have different longevity in the networks. Some (such as engaged individuals and environmental departments) are physically present and ready to transfer elements for long time periods, while others (such as test vehicles) are only present for shorter periods of time. This does not mean that the elements the test vehicles transport are short-lived - they may stay in the networks for much longer than any individual or department. However, the test vehicle after completion cannot adapt to accommodate changes in the networks as individuals or departments can.

Often more than one vehicle for translation appears simultaneously. In fact, in accordance with the basic networking mode in ANT, there is probably a need for more than one vehicle to make an impact. For instance, a test vehicle needs engaged individuals in order to be created with a concern for the environment; it also needs reports to document the relevant environmental issues and this in turn may require an environmental department or a research institution in order to be written.

The list of mediators and the connection to the ideas they carry highlights that it may be difficult to differentiate between the ideas themselves and the means to transport them. Rather than being a problem of separation, this can be understood as an opportunity for the involved ideas and mediators to mutually influence each other. The substantial ideas and the mediators that let them travel become coloured to such an extent that it can be hard to sort one from the other.

The vehicles of translation may be seen as hybrid constructions consisting of material from both the economy and the environment. To be effective in the logistics involved in getting ideas from one to another, they must be able to communicate in both networks.

Although the primary goal of the thesis was to reveal properties of the relationship between the economy and the environment and these constitute the main findings, knowledge was also created during the descriptions of each of the separate networks. This is the issue of the next two sections.

6.1.2 The content and the development of the economy

In the chapter on the Economy*, we could see how actors, resources and activities changed as continuous actions, reactions, re-reactions etc. took place. It was not just the interactions between the two actors in the relationship containing the focal resource that determined future directions - influences from relationships they had with other actors were also of great importance. Through a series of interactions, Volvo and Hydro (RA) moved relatively similarly to each other while the bumper changed character and economic properties.

The development of bumpers during the period from 1970 to 2006 has accentuated how *actors, resources and activities interplay to affect what is looked upon as economy*.

The companies developed a strong relationship, starting from the date when RA started producing bumpers for Volvo in the 1960s and continuing long into the 1980s. During that period, RA became the sole supplier of bumpers to Volvo and made heavy investments in plastic cap production and painting facilities. It was shown that:

> *A relationship with close links provides stability and room for development. Elements are adjusted towards greater harmonisation.*

The technical elements (comprising actors, resources and activities) generating revenues and costs are measured and understood with the aid of organisational elements (also comprising actors, resources and activities). There is thus an interaction between the technical and organisational elements making up the economy.

The technical solutions developed by RA and ÅSV to build an aluminium bumper that could accommodate US legislation at the beginning of the 1970s created several new customers for RA. The company had shown that it was indeed possible to create a strong bumper without having to increase weight too much and several European car manufacturers exporting to the USA became customers of RA in the first half of the 1970s. Volvo was the biggest customer for RA throughout the period and as RA learnt (both in relation to technology and to organisation) from other relationships, the bumpers in the relationship between Volvo and RA improved as a result. Thus, one conclusion is:

> *Having many relationships ensures access to various technologies and opens the possibility for innovation.*

In the early 1990s, the volumes going from RA to other customers than Volvo increased and consequently the share of the total volume produced at Raufoss for Volvo decreased; a trend that was enforced after Hydro's takeover at Raufoss. Although substantial investments were made in plastic cap production (for Volvo), this looked more like an investment to be able to sell the whole plastics department rather than a specific investment for Volvo. In fact, the intensity of the relationship decreased and contracts became less obvious than in earlier decades as the year 2000 approached. This showed that:

> *Maintaining a focus on a relationship consumes resources. There are therefore difficulties involved in having many close relationships at the same time.*

RA's struggles in the early 1990s and Hydro's subsequent takeover of RA, Volvo and Renault's attempt at merging in the same period and Ford's acquisition of Volvo in the late 1990s all pointed at the need for a large capital base in order to make investments. Such investments were necessary to ensure technological development and future profit. Thus:

> *The ability to innovate and make profit is connected to financial resources already present.*

Resources, activities and actors normally develop in small, almost invisible, steps from day to day. Only a few elements are able to affect the entire network to such an extent that changes can be spotted immediately. The US legislation connected to bumpers was an example of this.

6.1.3 The content and the development of the environment

In the chapter on the Environment*, we saw how series of translations have turned nature into calculable entities – into graphs and figures – describing potential environmental problems. During the period from 1970 to 2006, many environmental issues have been at the top of the agenda. Some have been refuted, some have been partly solved by technological measures and some never managed to hold on the weight they had gained initially. The bumpers' environmental properties thus changed several times during the time period from 1970 to 2006, not so much because of actual changes in the production or the composition or the weight of the bumpers themselves, but more because the environment itself changed. A continuing focus on an environmental issue requires a strong scientific base connected to potentially severe consequences, or in more general terms:

The number of connected actors and their ability to become black-boxed are determining the strength of environmental elements.

In order for an element to be connected to many others, it needs to be able to be translated without losing direction. In other words, it must be flexible enough to be contained in the network of other elements, yet strong enough to also dictate the other networks' direction. This means:

An element in the environment attains stability by the ability to enrol and align other elements

However, it seems that a large quantity of connections is not enough. Looking at the elements in the Environment* that have managed to create attention and to last from 1970 to 2006, it appears that elements with many relations to similar actors appear to vanish faster than those involved in networks with larger heterogeneity. Thus:

The stability of elements is encouraged by being connected within a heterogeneous network.

These conclusions may lead to the belief that environmental issues grow stronger and stronger for every connection they make to other elements. There is, however, always a "danger" for an environmental issue when a new connection is made. There is a real possibility that a connection to another environmental issue may lead to the first one being dissolved into the second. Such appeared to be the case for environmental impact categories such as acidification and eutrophication, which almost disappeared when climate change received increased focus. In more general terms:

New connections may deceive the "original" network, changing its content in a new direction.

Just like the problem of concentrating on several relationships in the economy, there is a problem in focusing on several environmental issues in the environment. LCA is an attempt to capture many environmental issues simultaneously, but when one category receives a lot of attention (such as in the case of climate change), other categories are silenced.

6.2 The thesis' implications for theories

This thesis has deliberately applied two theories – IMP and ANT – on the grounds that the issues to be investigated were spanning two networks with different content. It was deemed necessary that the theories employed were well connected to the networks to ensure that the instruments for capturing each of the networks were suitable for the task. The thesis thus did not intend to fill a gap in theory, but started out from a sense of puzzlement – a hesitation – connected to the relationship between the economy and the environment. Still, as with all theories, IMP and ANT may be confirmed and/or expanded through use. One of the more important implications for the employed theories is thus their usage to create the thesis. The successful production of descriptions of the Economy* and the Environment* shows that they are both useful theories for ordering empirical processes.

The findings presented earlier are strongly connected to the theories and thus emphasise their usefulness and their abilities to create insights. The findings may also be viewed as implications for theories themselves, as they are supporting and expanding the empirical base of IMP and ANT. Furthermore, combining the knowledge produced by employing them shows that they allow for communication, meaning that their basic assumptions about how the world works do not collide to the extent where communication is rendered impossible.

Placing the two theories together in a thesis also facilitates a comparison (at least implicitly) of their strengths and weaknesses and possibilities for cross-nurturing.

IMP's inclusion of the ARA model is smart because there is a defined purpose within the economy. Applying the ARA model to the environment could be an intriguing game, but the actual value of such an undertaking is more uncertain because the entities in the environment are not legal entities such as those appearing in the economy. They are not expected to employ resources to perform specific activities. The ever-present economic exchange underlying the structures and the processes (mutually defining each other) in the economy gives it specific characteristics. These characteristics make the ARA model useful for capturing the evolving economy as shown in this thesis.

The placeholders referred to as 'actors, resources and activities' therefore contribute to understanding the economy even before any empirical data is gathered. This gives IMP a certain edge over ANT in producing descriptions about or from the economy. The drawback is the risk that only elements already present in the economy may be used to develop the description, leaving the researcher blind to influences from elements outside the defined economy. Håkansson and Waluszewski (2002) escape this problem by extending the category of actors from business organisations to also include organisations such as Greenpeace. By focusing on the connections between the economy and another network, this thesis opens up considerations to understand more of how the economy influences and is influenced by other networks.

The paragraphs above contain references to some of ANT's strengths and weaknesses as employed in this thesis. The basic worldview ANT poses as a foundation for understanding the stability and development of networks is general and thorough enough for the theory to be applied to any entity. However, the interests and motivations for actors (both human and non-human) to form networks are absent or at least hard to keep an eye on (which may become particularly pressing in descriptions of the economy, one of the only networks with an unambiguous common currency: money). Its advantage of being a useful instrument for producing descriptions of all kind of elements is thus also a disadvantage, as it may miss the specifics of a certain network. This thesis has focused on the role of science in producing the environment and has shown ANT's ability to capture how nature is translated into writing and expose important elements in granting stability to environmental issues.

From the insights above, it becomes evident that IMP could learn from ANT how to expand their analyses, how to open up for non-industrial elements. For its part, ANT could learn some specifics of the economy from IMP. There are, however, good reasons for questioning whether a melange of the two theories would be a more useful tool for any study. Perhaps an important implication of the thesis is that you may need more than one theory when investigating complex problems that reside in more than one (theoretical) network.

The application of both IMP and ANT in the same thesis has actually made me more faithful to each of the theories when producing the descriptions of the Economy* and the Environment*. ANT's exhortation to stick to the empirical without reverting to a theoretical reservoir has influenced the rigorousness of the description of the Economy* in a positive manner. It has led to more thorough investigation of what elements that have been present and a stronger belief that the descriptions of relevant actors, resources and activities really cover what the Economy* is. At the same time, IMP's cleverness in creating analytical tools has influenced the way ANT has been employed to describe the Environment*. The exercise with IMP has increased the ability to visualise and present the Environment*.

During the argument for why two theories were employed in Chapter 2, a promise was made to include a discussion of why IMP and ANT have (or at least seem to have) different views on stability and change.[139] From the descriptions of the Economy* and the Environment*, it was not obvious that the difference is real, although the Economy* contained more stability than the Environment*. When reflecting upon the reasons for this, the importance of the choice of study object is highlighted. Since the bumper beam is an industrial product manufactured with the use of heavy machinery, it requires some dimensions to be stable. The bumper beam is not a scientific product to the same degree, and less is probably invested to keep the bumper beam and its environmental characteristics stable. When searching through the references on IMP and ANT, this trait seems to be quite general. In other words, IMP studies investigate products, relationships or other entities that at the outset are (more or less explicitly) chosen because they have had a certain degree of stability. ANT studies, on the other hand, most often choose to examine objects that are disputed and, if they are stable instead, the aim becomes to search for the controversies involved in making them so. Thus the difference seems to be related to choice of study objects and the choices regarding what to focus on. This did not pose any major problems for this study, but consideration needs to be given to what the theories are applied to and for.

The research design employed may also have implications for theories, as there is quite a strong link between theories and how to undertake studies. The empirical material is based on a longitudinal study spanning almost 40 years. Such a relatively long time perspective was chosen to ensure that there were actual changes in both the economy and the environment. This laid the foundation for tracking elements involved in their development. The study showed the design to be useful for such a purpose. There is, however, a danger in placing too much emphasis on single events or single elements when describing evolution and missing the details of daily activities.

Furthermore, there may be important contributions to theories other than those employed in this thesis. Many approaches where the economy and the environment are treated simultaneously have a propensity to treat one of them as constant. Hence, the boundaries of one of the objects are well confined, while the other is allowed to change. For instance many articles on various environmental economics such as "green logistics" and "environmental marketing" contain a static version of the environment, while the economy is allowed to change in order to accommodate the environment that is brought in. This thesis has shown that there is also a reason to maintain open boundaries for the environment.

[139] IMP focuses on how stability facilitates change, while ANT sees stability as the exception that has to be explained.

There are fewer examples of approaches to environmental science where the economy is explicitly treated. Elements from the economy such as specific production processes or production materials are often brought in to point at environmental problems they potentially cause, but there seems to be little consciousness to the processes and how elements are combined in the economy.

One exception to the approaches described above is industrial ecology, concerned with producing insights both about industry and about the environment and combinations of these. This does not mean that industrial ecology would have no use for this thesis. To the contrary, the content of this document should be also be of interest when it comes to understanding the grounds for production of the economy and the environment within industrial ecology.

6.3 The thesis' implications for practices

The purpose of this section is to highlight how the thesis findings could be used by people in any of the networks included in the thesis, e.g. business managers, scientists, environmentalists or politicians. Whether you are a business manager wanting to make your business more 'green', a scientist exploring the nature of nature, an environmentalist trying to understand why changes happen so slowly or a politician searching for the right measures to connect the economy and the environment, the findings can give an enhanced understanding of:

- What vehicles of translation to employ in order to transfer elements between networks
- Why attempts at transferring elements between networks are successful or why they fail
- How elements may change upon transfer

Although the information contained in the thesis is specific for the case of bumpers, it should be possible to transfer the findings to other practices. Specific vehicles for translation will vary depending on the characteristics of the matter they are involved in, but they will probably share similarities with those displayed here. Understanding how vehicles for translation operate can provide useful input for strategies when connecting the economy and the environment. Such understanding can of course also be used negatively. If you want a company to have an environmental image without having to impose changes, this thesis almost provides you with the perfect recipe.

The worldview presented in this thesis is probably just as important as the more instrumental implications.[140] The emphasis on networks – on the relational character of the world – and the downplayed role of human actors may imply that managers or politicians should focus more on combining elements and less on steering and control. However, the opposite argument can of course be valid: if everybody is only working on combining elements instead of taking control, no direction will ever be imposed on any elements. It is exactly this duality that is one of the thesis' main implications. Resources and activities in the economy and non-human actors in the environment need human actors to be aligned. However, without resources and activities or non-human actors, human actors are not granted the ability to move. There is thus a mutual dependency between these entities that defines how networks appear at a specific point in time and how they evolve.

Even if you disagree with the ontology presented here it may enhance your understanding of the world. Knowledge is explained and refined when opinions clash and spokespersons must defend their positions. This process may also take place inside the reader when reflecting upon the text. Thus, if you disagree with the assumptions underlying the thesis or the descriptions or findings it contains and have still continued to read through it, I hope your reasons for refuting the thesis (or parts of it) have become better defined.

6.4 Suggestions for further research

There are many possible avenues for extending what is done in this thesis: the issues at hand can be investigated with other empirical material, the empirical material from this thesis can be used for other issues and new empirical material can be used for new issues connected to the issues here. A few examples of pursuing these possibilities are provided in this section.

6.4.1 Possible empirical avenues

The basic premises of this thesis were that industry is instrumental in creating the economy and science is equally instrumental in creating the environment. However, there have been several examples of other networks that have included elements from the economy or the environment or both; most noticeably the legal network, the political network and the media network. It could be interesting to examine all these networks in order to better understand the relationship between the economy and the environment.

[140] This is based on a fundamental belief in research providing descriptions that may enhance the understanding of the world.

This is not to say that all industrial networks or scientific networks are exhausted through this thesis. The automotive industry may be special and other industrial sectors may thus show other characteristics relevant to both travel routes and vehicles for translation, which again may give additional insights into the relationship between the economy and the environment. For instance, could interesting knowledge be provided by a study of the industry responsible for manufacturing instruments for scientific explorations of nature? In this thesis, where the artefact studied was clearly connected to the economy, most of the elements investigated travelled from the environment to the economy. Perhaps a study where the industrial product is more closely associated with the production of environment would provide more insight into the transfer from the economy to the environment

A different research design could be followed to expand the knowledge of how elements are transferred between the networks. Instead of a longitudinal study of a technical artefact where many elements transferred are described (as in this thesis), a specific study of one or a few elements can increase understanding of how different networks participate in the process and how vehicles for translation operate. Such a design is connected to exploring networks other than the industrial and the scientific networks.

The common feature of all these possible empirical avenues is that they will not only produce knowledge of the relationship between the economy and the environment, but will also contribute to the understanding of each of the networks respectively.

6.4.2 A first sketch of interlation: a suggestion for a theoretical concept

At a conference a few years back, I was reflecting on the shift from focusing on transaction to focusing on interaction associated with IMP's new formulation of economic structures. At the same time, I was working on the translation concept, i.e. on the transferring of something from one entity into something similar in another entity. I played a little with the pair of words, and started thinking about what an interlation could possibly be. It struck me that a shift of words from "translation" to "interlation" could have consequences for actor-network theory and for the understanding of what remains constant when an actor-network changes over time. This does not mean the concept is only interesting from an actor-network perspective. Just as Håkansson and Waluszewski (2002) refer to the concept of translation as also being important in an industrial setting, the concept of interlation should be able to be translated (or maybe interlated) to several settings.

To examine what an interlation might be, let's look at the word itself in relation to the words 'transaction', 'interaction' and 'translation'. The prefix 'trans-' can mean across, beyond, on or to the other side of, or into another state or place (Britannica Online Dictionary 2007). The prefix 'inter-' means between, among, mutually, reciprocally, shared by, or involving or derived from two or more. The ending '-lation' comes from the Latin word *latus*, the past particle of the verb *ferre* which means to carry or to bring. Thus, from the etymology of the words, interlation could mean to carry something in between. The relationships between the words are indicated in Table 6-3.

Table 6-3 The meaning of transaction, interaction, translation and interlation

	-action	-lation
Trans-	An act from one party to another	A "cargo" from one party to another
Inter-	An act between two parties	A "cargo" between two parties

From the table, we can see that going from trans- to inter- means going from a uni-directional to a bi-directional situation, thus making direction less obvious. This may also have implications for how time is perceived. Transactions and translation appear to be more instantaneous than interactions and interlations, as the latter two require two parties to react. Interaction and interlation make it harder to pinpoint just where the action or the "cargo" is residing, but being more difficult can also mean a better representation of how the process actually happens.

One of the important features of going from transaction to interaction in IMP was the inclusion of historicity. Economic exchange can no longer be viewed separately from past events. Interaction denotes a whole series of actions between actors and includes past actions as well as expectations of future actions.

This hints at an interlation including past "cargos" and possibly also expectations of future ones. An interlation may well be equal to an actor-network, or rather the common denominator that determines the boundaries of the actor-network both in space and time, for the interlation will by definition not be residing in any actor - it is that which exists in between. However, how useful can the concept of interlation be if it is just another word for an actor-network? The actor-network does not implicitly contain the time element, but is rather a picture of the process or structure creating stability for an element at a given point in time. The interlation would be the condensed actor-network containing all the various elements that have made up the idea at several points in time.

As such, it may provide a word for a "solution" to the conflict between economy and environment. A description of the "economent" or "environomy" that is acceptable to both the economy and the environment. An emission quota is one such concept, one interlation, which has the potential of pleasing both parties. One counter-argument may be that emission quotas are on a lower level than the environment or the economy, but remember ANT's refusal of any distinction between macro and micro. An emission quota, as an idea, can contain the entire economy-network and the entire environment-network (or at least their interlations). Of course, there is an inherent danger in stating that everything is connected to everything. Although true, such a statement is not particularly fruitful in guiding our understanding of the world. The important point here is the analytical potential, or how we manage to sort our images of how elements make up the world we are part of.

It might be worthwhile to explore the concept of interlation further...in another thesis.

7. References

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Appendix A: List of interviews

Name	Organisation	”Mode”	Date
Jan Inge Skar	Hydro	Telephone	27.05.2004
Johanna M. Øster	Hydro	Telephone	08.06.2004
Arne Skoland	Hydro	Telephone	24.06.2004
Ola I. Moen	Hydro	Face to face	29.06.2004
Kolstein Asbøll	Hydro	Several	06.07.2004 and onwards
Tobias S. Kåvik	Hydro	Several	26.10.2004 and onwards
Pål Brekke	Hydro	Several	16.11.2004 and onwards
Jostein Søreide	Hydro	Telephone	05.12.2004
Eeva Liisa Book	Volvo	Telephone	06.12.2004
Mats Bengtsson	Volvo	Several	06.12.2004 and onwards
Jørund Buen	Point Carbon	Face to face	12.12.2004
Anders Kärlberg	Volvo	Telephone	08.09.2005
Mats Williander	Volvo	E-mail	12.09.2005 and onwards
Lisbeth Persson	Volvo	Telephone	23.09.2005
Mihkel Laks	Volvo	Face to face	06.10.2005
Mats Hildell	Volvo	Face to face	06.10.2005
Stefan J. Tingström	Volvo	Face to face	06.10.2005
Anna Paulsson	Volvo	E-mail	14.10.2005
Thomas Rozman	Volvo	E-mail	17.10.2005
Peter Holmén	Volvo	Face to face	24.11.2005
Tony Wickström	Volvo	Face to face	09.01.2006
Jørn Helge Dahl	Hydro	Several	14.03.2006 and onwards
Bjørn-Anders Hilland	Hydro	Several	15.03.2006 and onwards
Grete Valheim	Hydro	Face to face	15.03.2006 and onwards
Morten Aass	Hydro	Face to face	15.03.2006

Aage Larsstuen	Hydro	E-mail	20.03.2006 and onwards
Malin Persson	Volvo	E-mail	27.04.2006
Ørnulf Myhre	Hydro	Face to face	15.05.2006
Erik Bågarud	Hydro	Face to face	15.05.2006
Anita Lindberg	Volvo	Face to face	31.05.2006
Torgeir Welo	Hydro	Telephone	15.06.2006
Claes Rydholm	Volvo	E-mail	20.06.2006
Martin Weiman	Volvo	E-mail	26.06.2006 and onwards
Roy Jakobsen	Hydro	E-mail	14.08.2006
Sigurd Rystad	Hydro	Face to face	25.08.2006 and onwards
Thor Wang	Hydro	Face to face	25.09.2006
Per Harald Sørlien	Plastal	Face to face	09.10.2006
Roger Kyseth	Hydro	Face to face	09.10.2006
Yngve Langsrud	Hydro	Face to face	10.10.2006 and onwards
Tom Wasenden	Hydro	Face to face	10.10.2006
Pål Prestrud	Cicero	Face to face	13.10.2006
Kristin Dahl	Volvo	E-mail	13.04.2007
Jan P Røssevold	Norwegian Road Federation	E-mail	16.04.2007
Elisabeth Dahlquist	Volvo	E-mail	24.05.2007
Gunnar Falck	Volvo	Telephone	14.06.2007

Appendix B: Search procedure for the environment

Literature databases and search engines employed to gather information about the Environment* (and also about the Economy*):

Bibsys:	http://www.bibsys.no
ISI web of science:	http://isiknowledge.com
Society of Automotive Engineers:	http://www.sae.org
Science Direct	http://www.sciencedirect.com
JSTOR	http://www.jstor.com
Ebrary	http://site.ebrary.com
EBSCOhost	http://search.ebscohost.com
Google scholar:	http://scholar.google.com
Google	http://www.google.com
Wikipedia	http://wikipedia.org

It might seem unnecessary to include such a large number of literature databases, but it was soon discovered that the content varied largely between them both regarding the scope of different sciences and also their abilities to deal with chains of citations.

The starting point for the Environment* was found by performing searches in all databases including combinations of one of the following keywords:

bumper,
bumper beam,
reinforcement bar,

with one of the following keywords:

aluminium,
aluminum, (because of the different spelling in British English and American English),

and one or more of the following keywords:

environment,
pollution,
emission,
climate change,

global warming,
acidification,
eutrophication,
ozone,
ozone depletion,
smog,
sustainable development,
biodiversity,
toxic,
toxicity,
carbon dioxide,
carbon monoxide,
nitrogen, and
sulphur.

The search was also performed with Norwegian and Swedish keywords. After finding the Thiel-article, the search switched to tracking references to and from that particular article but supplementing with other articles and additional information on organisations and journals. The reason for the extensive search was both because the Thiel-article took time to find and it was not an obvious choice in earlier drafts of the thesis. Several rounds were performed in order to connect technical articles on aluminium bumper beams to environmental issues.