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Structural Influences on Organizational Learning

Two Case Studies of Introduction of New
Technology

Øystein Sikora Ingstad
Jennie Cecilie Karlsen

Industrial Economics and Technology Management
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Supervisor: Jonas Alexander Ingvaldsen, IØT

Norwegian University of Science and Technology
Department of Industrial Economics and Technology Management

Task Description

This thesis shall examine how the organizational structure influences an organization's ability to learn during introduction of new technology. This will be done through qualitative data collected from Norsk Hydro ASA.

Preface

This master's thesis marks the end of a five-year program in Industrial Economics and Technology Management at the Norwegian University of Science and Technology. In addition to complete our academic degrees, this thesis will also serve as a deliverable to the research project Step Changes in Mature Production Systems. It is therefore our hope that the findings and insights discussed here will be of value to researchers and practitioners involved in the project.

Several people have provided their support and guidance during the work with this thesis. Without you, this thesis would not have reached this level. First, and foremost, our supervisor Jonas A. Ingvaldsen. We would like to use this opportunity to thank you for your guidance throughout this semester. Your expertise on the subject, the many discussions we have had with you, your critical reading and feedback on our drafts have been highly appreciated. We would also like to thank our co-supervisor Vetle Engesbak for the contribution in the data collection process, and your help with this thesis. Lastly, we would like to thank Silje Grønning for the cooperation with the data collection process, as well as the tips and experience you have provided us about how to write a master's thesis.

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Abstract

Staying at the forefront of technological advancement is critical for a broad range of organizations based in high-cost countries, such as Norway. They must continuously develop and integrate new technology into their existing production systems. This introduction of new technology requires learning in several parts of the organization. However, current models of organizational learning fail to explain the learning processes that takes place during introduction of new technology. Furthermore, the prevalent view regarding the structural influences on organizational learning seems underdeveloped with respect to introduction of new technology. Organizations are encouraged to reduce formalization and decentralize authority to increase their organizational learning capabilities. This seems counterproductive for organizations that develop new technology in functionally differentiated R&D units and seek to integrate this technology in large, interdependent production systems.

To address these issues, this thesis empirically examines the structural influences on organizational learning during introduction of new technology. Through a comparative case study, two technology introduction projects are analyzed in detail.

Four processes are found to contribute to organizational learning during technology introduction: *technology development* is fundamental for the organization to acquire necessary knowledge, extensive *problem identification* is important to fully understand technical problems, the organization must *find and connect* relevant knowledge, skills and technological artefacts across its units, and to *integrate technology* the organization must be effective at combining knowledge from R&D with knowledge from operations. Each of these learning processes are influenced differently by different elements of the organizational structure. Differentiated R&D units positively influence the ability to develop new technology. However, this have a negative influence on the ability to find and connect the relevant resources. This challenge can be mitigated by having an integrating manager responsible for governing the relevant units. Too narrowly defined performance metrics negatively influence operations ability to identify the cause of their problems. The success of technology integration is positively influenced by a formalized interface in the form of a liaison position based in R&D.

Thus, some level of formalization and authority will in fact enhance organizational learning processes during introduction of new technology.

Sammendrag

Å ligge i forkant av teknologisk utvikling er avgjørende for en bred gruppe organisasjoner basert i høykostland, slik som Norge. De må kontinuerlig utvikle og integrere ny teknologi med deres eksisterende produksjonssystemer. Denne innføringen av ny teknologi krever læring i flere deler av organisasjonen. Gjeldende modeller for organisasjonslæring er derimot ikke i stand til å forklare de læringsprosessene som finner sted under innføring av ny teknologi. Organisasjonen oppfordres til å desentralisere autoritet og redusere formalisering for å øke sin evne til organisasjonslæring. Dette fremstår mot sin hensikt for organisasjoner som utvikler ny teknologi i funksjonelt differensierte FoU-enheter, og integrerer denne teknologien i store og gjensidig avhengige produksjonssystemer.

I hensikt å adressere disse utfordringene undersøker denne oppgaven de strukturelle påvirkningene på organisasjonslæring under innføring av ny teknologi. Gjennom en komparativ casestudie blir to teknologiinnføringsprosjekter analysert i detalj.

Fire prosesser bidrar til organisasjonslæring under teknologiinnføring: *teknologiutvikling* er fundamentalt for at organisasjonen tilegner seg nødvendig kunnskap, omfattende *problemidentifisering* er viktig for å forstå tekniske problemer fullt ut, organisasjonen må *finne og koble* relevant kunnskap, ferdigheter og teknologiske artefakter, og for å *integrere teknologi* må organisasjonen kombinere kunnskap fra FoU med kunnskap fra drift. Hver av disse læringsprosessene påvirkes ulikt av ulike strukturelle elementer. Differensierte FoU-enheter har en positive påvirkning på evnen til å utvikle ny teknologi, men har en negative påvirkning på organisasjonens evne til å finne og koble relevante ressurser. Denne utfordringen kan dempes ved å oppnevne en posisjon ansvarlig for integrering av teknologi mellom enhetene. For smalt definerte måltall har negativ påvirkning på evnen drift har til å finne årsaken til sine problemer. Et formelt definert bindeledd mellom drift og FoU har positiv påvirkning på integreringen av ny teknologi.

Det er altså slik at en viss grad av formalisering og autoritet faktisk kan forsterke de organisasjonslæringsprosessene som finner sted unner innføring av ny teknologi.

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Introduction 1

Since Argyris and Schön (1978) pioneered the concept of organizational learning the field has gained considerable interest among researchers and practitioners, as the ability to learn is shown to be a source of competitive advantage (e.g. Argote and Miron-Spektor, 2011; Levinthal and March, 1993; March, 1991). In particular, organizational learning is said to increase average performance and produce more reliable outcomes (Levinthal and March, 1993). Due to its wide appeal, organizational learning has been conceptualized in different ways by different streams of research. A general conceptualization is that organizational learning “means the process of improving actions through better knowledge and understanding” (Fiol and Lyles, 1985, p. 803). Thus, a central focus within the field has been to identify and understand the various processes that drives organizational learning (e.g. Huber, 1991).

In this thesis we will focus on the organizational learning processes that take place during introduction of new technology. Due to high labor cost, Norwegian industrial production companies have become particularly dependent on being at the forefront of technological advancements to maintain their competitive advantage. Therefore, being effective at introducing new technology is essential. In fact, the Head of Technology at the case company has explicitly stated that “the key to success in this industry is maintaining our technological competitive advantage”.

However, the organizational learning processes that takes place during introduction of new technology is not sufficiently covered in the existing literature. Introducing new technology into an existing system of interdependent technologies is a complex process as it requires a thorough assessment of how new technology can be reconfigured to conform with the requirements of the existing system. This requires specialized bodies of knowledge within specific scientific fields. In these situations, organizational learning is not primarily driven by an accumulation of experience in operations, but rather by a deliberate effort to develop and modify new technology in the *Research and Development* (R&D) unit. Thus, the extensive literature on experiential learning and learning curves (e.g. Argote and Epple, 1990; Argote and Miron-Spektor, 2011) fails to explain all relevant learning processes during technology introduction.

Furthermore, the prevalent view on the influence of organizational structure on organizational learning transfers poorly to technology introduction. The consensus regarding structural influences on organizational learning is largely drawn from the innovation literature (e.g. Burns and Stalker, 1961; Trott, 2008). To improve their learning capabilities, organizations are encouraged to move away from formalized and complex structures, towards a decentralized structure with a higher degree of autonomy (Fiol and Lyles, 1985; Meyer, 1982). Certainly, moving in this direction may enhance organizational learning in small and creative organizations, but that does not mean the same will be true for a large technology-driven organization. Developing, transferring and integrating technology on a large scale depend on teams of researchers, as well as a formalized coordination with the operating units. Therefore, an informal structure is largely infeasible. Moreover, Bunderson and Boumgarden's (2010) study of self-managed teams showed that structural factors such as specialization, formalization, and hierarchy can in fact promote learning at the group level. This shows that there is no inherent contradiction between learning and a formalized structure. Therefore, a question can be raised whether formalization necessarily is bad for organizational learning. In fact, few studies have thoroughly examined the influence of structure on organizational learning (Hong, 1999). Thus, further research on this matter is warranted.

It seems apparent then, that there is a need to deeper understand the organizational learning processes during introduction of new technology, and the structural influences on these learning processes. Therefore, the following research question is proposed:

> *How does organizational structure influence organizational learning during the introduction of new technology?*

Through a comparative case study this thesis will attempt to answer the above research question. Two different cases of technology introduction, within the same case company, will be studied. The answer will be developed through separate within-case analyses, followed by a cross-case analysis. For each of the analyses, the organizational learning processes during introduction of new technology will be identified. Then, the structural elements that influence these learning processes will be identified and analyzed. The findings are summarized in a conceptual model for structural influences on organizational learning.

1.1 Structure of the Thesis

The thesis is structured as follows. Chapter two presents the theoretical framework for the thesis. This chapter starts out by reviewing technology, before it moves on to review the relevant parts of the literature on organizational learning and organizational structure. In addition to provide an overview of previous literature, the purpose of this chapter is to establish the terminology that will be used throughout the thesis. Chapter three, methodology, presents and discusses the research strategy, research design, research method and how the empirical data was analyzed. In chapter four, the empirical data is presented and analyzed, and the answers to the research question are developed. Chapter five discusses the findings in relation to prior theory. Lastly, chapter six, concludes the thesis, discuss its limitations and and outlines paths for further research.

Theoretical Framework 2

The research conducted in this thesis is situated at the intersection of organizational learning and organizational structure. These are both extensive theoretical fields in their own right, and a review of past literature is necessary in order to position our contribution to theory. However, as indicated in the introduction, the thesis is focused on the introduction of new technology. This focus has implications for the subset of theory that is most relevant. Thus, this chapter will start by reviewing the concept of technology in an organizational context, and show how it is related to organizational learning and organizational structure. Following this, the concept of organizational learning will be defined, relevant learning models will be presented and their relation to technology introduction will be discussed. Lastly, the concept of organizational structure will be defined, and the relevant structural elements will be reviewed.

2.1 Technology in the Organization

2.1.1 What is Technology?

Despite being a widely used term, technology is not a straightforward concept to define. In particular, its relation to organizations is not equally interpreted in the literature (Orlikowski, 1992). Because technology plays a pivotal role in this thesis it is necessary to review this debate in some detail. Moreover, we must first establish a common understanding of what technology is before we can review how new technology is introduced into organizations and how this is related to organizational learning.

Orlikowski (1992) argues that previous conceptualizations of technology have tended to focus only on some aspects of technology, at the expense of others. Two aspects of technology are highlighted as particularly important for conceptualizing technology. First is the scope of technology, meaning "what is defined as comprising technology" (Orlikowski, 1992, p. 398). Previous studies vary in terms of what is considered part of the technology. In one end technology is considered only as the physical equipment or machines. On the other end it is considered to include all the skills and knowledge possessed by the operators and engineers using and building the machines. Second is the role of technology, meaning how the interaction between organizations and technology is defined (Orlikowski, 1992, p. 398). Previous studies differ in the extent to which they consider technology as an external factor with a deterministic effect on the organization, or shaped by the members of the organization, through common understanding and interpretation. Thus, it is apparent that technology can easily be understood and conceptualized in different ways. In order to avoid unclear usage of the concept, the view of technology held in this thesis will be stated explicitly in the following paragraphs.

In terms of scope, we will adopt a view of technology similar to the the threefold disaggregation of technology into knowledge, skills and artefacts given by Metcalfe and Boden (1992, as presented in Coombs, 1996). Technology as knowledge is "the formal abstract representation of technology in a codified form" (Coombs, 1996, p. 351). Technology as skill represents the specific capabilities to make use of technological knowledge. Technology as skill is therefore related to the humans involved in developing the technology. Lastly, technological artefacts include all the physical objects incorporating a set of technologies. Together these three concepts comprise distinct but related parts of the technology existing in an organization. With respect to Orlikowski's (1992) discussion this view must be seen as broad in scope. Taking a broad, but still distinctly three-folded view on technology allow us to capture how different forms of technology relate differently to organizational learning, as well as the different structural elements influencing the process.

According to Orlikowski (1992) there are three different views on the role of technology. Early researchers "assumed technology to be an objective, external force that would have deterministic impacts on organizational properties such as structure" (p. 398). Later researchers shifted the focus to the human aspect of technology, seeing it as a product of social actions and shared interpretations. The more recent researchers have combined the two early streams of research. By these researchers technology is assumed to be an "external force having impacts, but where these impacts are moderated by human actors and organizational contexts" (Orlikowski, 1992, p. 400). In terms of technology as role we adopt the latter view. In relation to introduction of new technology it is of particular interest to note that different parts of the organization have different interactions with technology. While some units develop technology for the organization, others make use of it. The first group can be seen as actively moderating the influence of technology on the organization, while the second group may perceive it as an external force on their routines.

In conclusion, the view is taken in this thesis that technology comprise of technological knowledge, technological skills and technological artefacts. Each constitute distinct, but related parts of the technology in an organization. Each of these elements are tightly linked to the social actors in the organization. They may be created and modified by human actors, but they may also influence the actions taken by human actors. Equipped with this conceptualization of technology we can move on to review the process of introducing new technology into an organization.

2.1.2 Introduction of New Technology

By introduction of new technology, we mean the process of bringing new technology to the organization, and put it into operational use. Thus it includes two important sub processes. First, the process of acquiring technology, either through in-house development or through external sources. Second, the process of integrating the technology in a product or production process. Building on Coombs's (1996) description of technology, the result of technology introduction could materialize itself as an increase in the knowledge or skills possessed by members of the organization, and as a new or improved technological artefact.

2.1.2.1 Technology Acquisition

Technology is of such a nature that it has to be developed by people with expertise in the relevant fields. Organizations may either have the expertise to develop the technology themselves, or they may purchase already developed technology from external sources. According to Coombs (1996) one of the responsibilities of the R&D unit is namely "to acquire, generate and manage the technological capabilities of the company" (p. 349). The technology that is generated internally is often developed in a separate R&D unit in the organization. However, companies are not always able to cover the whole spectrum of relevant technologies internally. Therefore, the company often have to rely on external linkages in addition to the internal R&D units, such as public science and technology assets of collaborators (Coombs, 1996).

2.1.2.2 Technology Integration

For organizations where technology constitutes parts of their competitive advantage it is critical to stay on top of technical advancements in the industry. As the level of technology in the industry as a whole improves, it becomes critical for the individual firm to adapt and introduce new technology into its own organization. In most industries new technology rarely replaces all of an organization's current technology. Thus, it becomes critical for the organization to make new technology fit into the existing technological system. Described as a matter of technology integration, these issues have been subject to study by some researchers (e.g. Iansiti, 1995; Pisano, 1994).

Iansiti (1995) views the creation of new products or processes as a matter of combining new technology with already existing technology within the organization. Thus, in order for organizations to successfully apply new technological knowledge they must carefully consider the impact of new technology on the existing technology (Iansiti, 1995). Therefore, understanding the characteristics of the existing technical system becomes very important. Large industrial production systems have several technological interconnections. Understanding how these interconnections are related, and how they respond to changes are important when introducing a new component into the system, as this component must conform with the existing components and technologies.

This view is supplemented by Pisano (1994), who argues that new technology has to be coupled with the operating conditions. According to Pisano (1996) the most challenging and problematic aspects of product development lies in the development and application of new process technology in operations. A situation that sometimes occurs in organizations is that the R&D unit comes up with an idea that works well in theory, and shows satisfactory results in laboratory experiments. However, when applied in operations it does not produce the same results. Pisano (1994) suggests three explanations of the deviation in performance between lab and operations. It can be due to differences in scale, differences in the way factory workers and researchers perform certain operating tasks, and differences in the equipment used in the research and development phase and the equipment used at the plant.

These challenges of technology integration have two important implications for organizations attempting to introduce new technology. First, it is important to understand how the environment in which the technology is to be applied differs from the environment in which it was developed and tested. Second, new technical possibilities should not be selected for their individual potential, but for their impact on the processes and products as a whole (Iansiti, 1995). Thus, in order for the new technology to provide improved performance it has to fit with existing technology and capabilities. Therefore, as argued by Pisano (1994), cross-functional integration between R&D and operations becomes particularly important in process development. For the organization to be able to simulate processes and to anticipate production needs, a continuous feedback from production to R&D is needed (Pisano, 1996).

2.1.2.3 Learning During Technology Integration

Pisano (1996) argues that learning about whether, and how, new technology can be integrated in the processes is an important part of technology integration. This learning can either take place *before doing* or *by doing*, depending on the knowledge required to develop and integrate the new technology. If the organization already has a deep theoretical knowledge, which makes it possible for them to predict the cause and effects of a new technology, the plant is not critical in the development of new technology, and most of the learning takes place before the process is transferred to the plant. This learning can take place through “computer simulations, laboratory analyses, prototype testing and pilot production” (Pisano, 1996, p. 1098).

In industries such as aluminium production, pharmaceuticals and semiconductors, product and process designs are highly interdependent. This means that changes in process technology can have significant impact on other parts of the process and the end product (Pisano, 1996). In such organizations, it is not always possible to predict the cause and effect relationship of a new technology, which makes learning before doing harder to achieve. Laboratory experiments are not representative for performance in the factory, as there are major differences between the laboratory and the factory. In order to improve the fidelity of an experiment, the testing conditions should be as close to operating conditions as possible (Pisano, 1996). Therefore, the experiments should be run in a pilot facility, or directly in operations if possible. “Some things can only be learnt by running the process in the factory” (Pisano, 1996, p. 1101). In such cases, the involvement of the plant is crucial for the the development of new technology, and to learn by doing.

It should be apparent from the above review that introduction of new technology is tightly related to both organizational learning and organizational structure. The processes of developing technology and integrating technology are in their own examples of organizational learning. Moreover, the simple fact that technology is frequently developed in one organizational unit and integrated in another makes this process highly dependent on the structural design of the organization. For example, it was argued that cross-functional integration between R&D and operations is of critical importance in order to assure fit between new and existing technological capabilities. How to successfully achieve such cross-functional integration is in the domain of organizational structure.

2.2 Organizational Learning

This section will start by establishing an understanding of knowledge and information, highlighting a conceptualization of knowledge that is particularly relevant when discussing development and use of technology. Then, we will give a brief introduction to organizational learning as a field of research, highlighting the different views of the concept, and state our own position. Lastly, we will review a range of organizational learning processes and discuss their relevance for introduction of new technology.

2.2.1 Knowledge and Information

Knowledge is central to theory on organizational learning. Researchers within the field have often referred to organizational learning as development of new knowledge, or as a change in the state of knowledge in the organization (Fiol and Lyles, 1985; Lyles, 1994). Therefore, to discuss theory on organizational learning we must first establish a common understanding of knowledge. However, to define or conceptualize knowledge is no trivial task. Consequently, the concept is treated in various ways by previous literature. Moreover, knowledge is sometimes used in combination, or seemingly interchangeably, with information. It is therefore necessary to go into some detail in describing knowledge, information and the relation between them.

2.2.1.1 Information

Information in itself is somewhat simpler to describe than knowledge, and is therefore presented first. Kogut and Zander's (1992) view on information presents useful insight: "By information, we mean knowledge which can be transmitted without loss of integrity once the syntactical rules required for deciphering it are known" (p. 386). Thus, information can be seen as the concrete words and numbers that objectively exist in an information system or on a piece of paper. If we attribute no meaning to it, and only consider it for the particular combination of bits and bytes by which it is physically represented, this is indeed a very simple concept to handle. For example, information could easily be uploaded to an online storage, and would remain the same regardless of where, and by whom it is accessed.

However, the question of how information can result in knowledge is more complex. Nonaka (1994) provides an explanation of this relationship, suggesting that "Information is a flow of messages, while knowledge is created and organized by the flow of information, anchored on the commitment and beliefs of its holder" (p. 15). Thus, knowledge can be created from information, through human interpretation.

2.2.1.2 Knowledge

The literature presents a number of distinctions of knowledge. Polanyi's (1966) idea that human knowledge can be classified as tacit and explicit knowledge is one of the most common distinction made in the literature. Drawing on his ideas, Nonaka (1994) describes the distinction as follows: "Explicit or codified knowledge refers to knowledge that is transmittable in formal, systematic language. On the other hand, tacit knowledge has a personal quality, which makes it hard to formalize and communicate" (p. 16).

Even though explicit knowledge is possible to express in formal, systematic language it does not mean that it is straightforward to transfer between individuals. First of all, it is important to note that information does not translate one-to-one into explicit knowledge. As Polanyi (1969) outlines, it is problematic to think of explicit knowledge as an independent piece of knowledge. It is always dependent on the tacit knowledge. Thus, if a person gains some explicit knowledge from accessing information, the explicit knowledge gained is dependent on the knowledge already possessed by that person. Whenever we attribute meaning to information, we rely on our prior knowledge. This is described as the process of sense-reading (Polanyi, 1969). Conversely, if a person creates some information on the basis of his explicit knowledge, this will also depend on his tacit knowledge through the process of sense-giving (Polanyi, 1969). An implication of this is that the more two people differ in terms of prior knowledge, the harder it will be for them to exchange knowledge.

An implication of focusing on technology introduction is that certain types of knowledge will be particularly relevant. As discussed earlier, new technology is developed by an R&D unit, integrated with existing technology, and then used by operations. The knowledge required to develop new technology is of a different nature than the knowledge required to use technological artefacts in operations. A theory of knowledge that captures this distinction is provided by Pavitt (1998). Citing Nelson (1998) he distinguishes between a *body of understanding* and a *body of practice*.

Body of understanding refers to a form of knowledge that is "based on competencies in specific technological fields, and reflected in the qualifications of corporate technical personnel within the organization, and in the fields in which they patent and publish" (Pavitt, 1998, p. 436). For example, a researcher in a corporate R&D unit will typically possess knowledge within a set of academic disciplines such as electrochemistry or metallurgy, which is acquired through a formal education. Moreover, through scientific work in the R&D unit the researcher may acquire further and deeper knowledge within specific fields. Together, organizational members with this type of knowledge represent the body of understanding within the organization.

Body of practice is "related to the design, development, production, sale and use of a specific product model or a specific production line" (Pavitt, 1998, p. 436). This knowledge is firm-specific and is acquired through a combination of experimentation, experience and exchange of information across parts of the organization. For example, through experience, operators of a production process accumulate specific knowledge of how their machines are best used, and how they react to various inputs. Pavitt (1998) argues that the organization must seek to establish a body of practice that link the body of understanding with useful artefacts.

These two bodies of knowledge do not necessarily constitute an exhaustive model of knowledge, but they provide a useful taxonomy for describing two distinct and prevalent forms of knowledge in the organization. Noting the difference between a body of practice and a body of understanding is highly relevant for the introduction of new technology, as integrating new technology for use in operations would require an active combination of both bodies of knowledge.

2.2.2 What is Organizational Learning?

Equipped with a deeper understanding of knowledge, we can turn to the literature specifically on organizational learning. The field of organizational learning emerged during the nineteen-sixties, and is still a popular field of study (Dodgson, 1993). Despite its popularity, there does not seem to be a main stream of research in organizational learning. Moreover, just to agree on a common definition of organizational learning have proven surprisingly difficult (Fiol and Lyles, 1985; Huber, 1991). Consequently, several definitions and models exist. An implication of this somewhat confusing situation is that reporting research on organizational learning becomes increasingly difficult. Thus, in order for our thesis to make a clear contribution to the field, it is necessary that we review the different views on organizational learning, and state our own position clearly.

First, closely linked to organizational learning is individual learning. To what extent these two forms of learning have similarities, and consequently to what extent theory on individual learning can be applied to organizational learning, is one source of debate. Initial researcher in the field built heavily on what we know about human learning to theorize organizational learning (e.g. Argyris and Schön, 1978). Argyris and Schön (1978) describe organizational learning as the detection and correction of errors. A more detailed description of organizational learning is given in later work by the two: “Organizational learning occurs when individuals within an organization experience a problematic situation and inquire into it on the organization’s behalf” (Argyris and Schön, 1996, p. 16). The problematic situation is triggered by an observed mismatch between the expected and the actual results of an action. This conceptualization of organizational learning by Argyris and Schön (1996), could just as much have been used to describe individual learning. Later theorists have built ideas and models that to a larger extent incorporates organizational elements, such as transfer of knowledge between units, retaining knowledge in the organization and personnel turnover (e.g. Huber, 1991; March, 1991; Argote and Miron-Spektor, 2011). The common ground is found by many, through stating that individual learning is a requirement for, and thus part of, organizational learning, but that organizational learning cannot be seen as just the sum of all individual learning (Fiol and Lyles, 1985). Acknowledging that organizational learning encompass something more than individual learning, increases the need to sharply define what it actually is.

As a starting point, organizational learning can be seen as describing a causal relationship. The cause is a set of knowledge related activities occurring in the organization, and the effect is a corresponding change in the organization’s behavior. Starting with this general view of organizational learning allows us to outline the areas in which there are definitional disagreements.

2.2.2.1 What is the Cause of Organizational Learning?

Considering the cause of organizational learning, researchers provide a wide array of suggestions. Fiol and Lyles (1985) have a very general view, and suggest that organizational learning happens through gaining better understanding and knowledge: "Organizational learning means the process of improving actions through better knowledge and understanding" (p. 803). Other researchers goes some steps further in suggesting how this may happen. Huber (1991) suggests that "an entity learns if, through its processing of information, the range of its potential behaviors is changed" (p. 89). Then he extends this definition to organizational learning by arguing that the existence, breadth, elaborateness and thoroughness of organizational learning is caused by sub processes of knowledge acquisition, information distribution, information interpretation and organizational memory, respectively. On the other hand, there are examples of researchers that have had a narrower focus, such as Argote and Miron-Spektor (2011) suggesting that the cause of organizational learning is the acquisition of experience.

With respect to the cause of organizational learning, the common idea seems to be that members of the organization conduct some set of knowledge related activities, that lead to an overall increase in the level of knowledge in the organization. Introduction of new technology depends on several different knowledge related activities. First, the process of acquiring or developing new technology is one type of knowledge activity. Second, the process of integrating the new technology into the existing production system is a different knowledge activity. Third, making use of technological artefacts in operations is yet a different knowledge activity. Therefore, we will in this thesis adopt a broader view of the processes that contribute to organizational learning, along the lines of Huber (1991).

2.2.2.2 What is the Effect of Organizational Learning?

Considering the effect of organizational learning there is agreement across researchers that the effect of organizational learning is some change in the organization. This alone however, is not very insightful. The more interesting questions are about the nature of this change; what is changed, and in what way? In answering this, however, there are different opinions in the field. The organizational learning theory developed by Argyris and Schön (1978, 1996) focuses on a visible and behavioral change. Through correction of errors the organization changes its behavior. Building on this line of thought, researchers have argued that, not only is the effect of organizational learning a change in behavior, but more specifically an improvement in behavior (e.g. Fiol and Lyles, 1985). Moreover, there are examples of empirical research that have shown how organizational behavior improve as the organization acquire experience, leading to the idea of *learning curves* (Argote and Epple, 1990). However, there are researchers that argue against limiting the view on organizational learning to visibly behavioral improvements. Huber (1991) suggests that the effect of organizational learning should be viewed as a change in an organization's range of potential behaviors, i.e. organizational learning may not lead to an immediate and visible change in behavior. He argues that limiting the view on organizational learning to only include situations where performance has been improved is too strict, and can lead researcher to overlook interesting findings.

With respect to the effect of organizational learning we adopt the broader view proposed by Huber. Indeed, situations where performance is improved are of great interest, and will in fact be the primary concern in this thesis. Nevertheless, situations can easily be imagined where an attempt to introduce technology fails, but where the organization still gain important knowledge from it. Furthermore, a technology developed by a researcher will not lead to an improvement of performance in the organization until it is it put to use in operations. Even though a particular technological artefact is not put to use, or fails to work effectively, the knowledge gained in the process of developing that technology can still be useful for the organization. It is our opinion that these processes should be considered as part of the organizational learning as they lead to an increase in knowledge. To include them in our research we do not limit our view of organizational learning to performance improvement only.

2.2.3 Organizational Learning Processes

As noted earlier, prior research has varied substantially in how organizational learning has been defined. This is also reflected in the wide array of models and theories of organizational learning that have been developed. In a review of organizational learning, Huber (1991) argues that the field lacks cumulative work and synthesis of work from different research groups. Consequently, there exist several different models that are not clearly related. Some attempt to give an exhaustive overview, while other focus on specific concepts or processes within organizational learning. In his review, Huber (1991) makes an attempt to provide a more complete understanding of organizational learning. He therefore distinguishes four different groups of processes that contribute to organizational learning; knowledge acquisition, information distribution, information interpretation and organizational memory. Huber's framework provides a broad overview of the key issues that have concerned previous researchers in the field. Thus, his framework is adapted in the following review as a frame of reference for categorizing the organizational learning processes that are related to introduction of new technology.

2.2.3.1 Knowledge Acquisition

As was argued earlier, introduction of new technology means the process of bringing new technology into the organization, and put it into operational use.

Bringing new technology into the organization surely requires new knowledge to be obtained. Therefore, it is of great interest to go into some detail on how organizations acquire knowledge.

According to Huber (1991) “knowledge acquisition is the process by which knowledge is obtained” (p, 90). The literature on knowledge acquisition mentions several means as to how knowledge can be acquired. In his review, Huber (1991), discusses five processes through which organizations can acquire knowledge: congenital learning, experiential learning, vicarious learning, grafting and search. Congenital learning is the knowledge that the organization has from its creation. Vicarious learning and grafting considers that the organization may acquire knowledge outside its boundaries, from other organizations or by hiring new employees, respectively. Lastly, Huber’s (1991) concept of search is a collection of several processes that relates to monitoring the external environment as well as the organization’s performance for problems or opportunities. According to Huber (1991), these five sub process can substitute for each other, and more importantly different processes will be better suited for different purposes or situations. For example, in order to acquire knowledge that is new to the organization, grafting and vicarious learning would be a much faster approach than building the knowledge through experiential learning or search.

Experiential learning as a knowledge acquisition process has received much attention in the literature. Learning from experience is an important source of knowledge for operating units. Through experience they accumulate knowledge about how the different machines work best, and how they react to different changes. Therefore, experiential learning will be explained in more detail. Empirical studies found have found that the performance of the organization improves as the organization repeatedly performs the same tasks (Argote and Epple, 1990), and thus learning is argued to be related to the acquisition of experience. In this view knowledge is created through the interaction between experience and the organizational context (Argote and Miron-Spektor, 2011). Moreover, research on experiential learning have suggested that heterogenous experience is better than homogeneous, and that recent experience is better than older, in terms of learning outcomes (Argote and Miron-Spektor, 2011).

However, the role of experience as a source of knowledge has received some criticism. According to Levinthal and March (1993) experience is often a poor teacher, because it is an insufficient representation of the complex environment where the learning takes place. They argue that the organization uses simplification and specialization to facilitate learning from experience. By using these two techniques to make sense of the experience the organization runs the risk of suffering from myopia in its learning process. In particular, it leads to the tendency to favor the short run over the long run, the tendency to favor effects close to the learner, and the tendency to learn more from success than failure (Levinthal and March, 1993). This suggests that learning from experience as the only way to acquire knowledge limits the total learning potential of the organization.

Related to knowledge acquisition is the concept of absorptive capacity. According to Cohen and Levinthal (1990) an organization's ability to acquire new knowledge is dependent on its absorptive capacity. Absorptive capacity refers to an organization's ability to recognize the value of new external information and assimilate it into their own organization. An important argument in their work is that the absorptive capacity of an organization is largely dependent on the organization's prior and related knowledge. It is argued that a moderate level of prior knowledge in a related area is necessary to fully recognize the value of new external information. A consequence is that organizations are more likely to acquire knowledge in the fields they are already familiar with. This is often referred to as path-dependency in the literature (Cohen and Levinthal, 1990). Because of this phenomenon it is argued that it is necessary for an organization to invest in new areas of expertise early on, in order to be able to exploit the areas when they mature (Cohen and Levinthal, 1990).

With respect to introduction of new technology, the literature on knowledge acquisition seems partially lacking. Experiential learning is a good model to explain how operations are gradually improving by gaining experience with their current technology. However, none of the forms of knowledge acquisition described by Huber (1991) describe the process in which the organization develops new technology. Technology development is not a process of incremental improvement through repeatedly performing the same tasks, nor is at simply a matter of monitoring the market for opportunities or acquiring knowledge through new employees. However, it is still an example of a process where the organization acquire significant knowledge.

2.2.3.2 Information Distribution

With information distribution, Huber (1991) means the process by which information is shared between different parts of the organization. Information distribution is the determining factor for the breath and the occurrence of organizational learning. Huber (1991) claims that organizations often do not know what they know. By this it is meant that organizations tend to have weak systems for finding where information is stored within the organization (Huber, 1991). Given the idea that information distribution leads to a more broadly based organizational learning, this is problematic. If more people were aware of the information and knowledge available in the organization, more attempts to access it would have been done, and a broader group of the organization would be able to learn from it. Consequently, a broader organizational learning would have taken place. According to Argote and Epple (1990), the ability, or inability, to distribute knowledge and information within the organization is one of the explanations why organizational learning varies between organizations.

As Huber (1991) argues, organizations often do not know what they know.

Consequently, organizational units with potentially synergetic information is not aware of where it could serve and therefore does not know where to distribute it. Huber (1991) suggests internal employee transfer as a process that can facilitate the coupling of those who have nonroutine information with those in need of it.

However, during introduction of new technology, distribution of information alone is not enough. Since the technological artefacts are developed in R&D but taken into use elsewhere in the organization, namely in operations, the technology has to be shared between these two parts of the organization. A technological artefact cannot simply be codified as information and distributed to operations. Therefore, for organizational learning to take place during introduction of new technology a more extensive process to transfer technology as well as the associated knowledge of how to use it, is needed.

2.2.3.3 Information Interpretation

The information is interpreted when the distributed information is given one or more commonly understood meanings (Huber, 1991). In this regard, Huber (1991) argues that it is critical that the information is uniformly framed when distributed to different units. This to make sure that the information is also uniformly interpreted. This illustrates a very important point in that even if knowledge or technology is presumably successfully codified into easily distributable information there is no guarantee that the recipient will interpret the information in the intended way. Huber (1991) argues that "media richness is a determinant of the extent to which information is given common meaning by the sender and the receiver" (p. 103). According to Daft and Lengel (1986), the richest medium is face-to-face interactions because it provides immediate feedback that enables the sender to verify the recipient's interpretation. This is especially important when a technology is distributed from R&D to operations. When the technology that is to be integrated in operations is developed in a separate R&D unit, it is important that R&D correctly understands the needs of operations, and the state of their current technical system. Conversely, it is important that operations sufficiently understand how to use new technological artefacts developed in R&D. The implication of this is that technology should preferably be distributed through media rich channels, such as meetings, conferences and similar arenas where the involved individuals work together.

2.2.3.4 Organizational Memory

The last construct in Huber's (1991) review is related to storing of knowledge for future use, referred to as organizational memory. According to Huber (1991) there are three challenges related to the storage of knowledge in organizations. First, personnel turnover may lead to the loss of people that possess important parts of the organizational knowledge. This causes the human components of the organization's memory to get lost (Huber, 1991). The second challenge is related to the non-anticipation of future needs. As a result, great amounts of information are not saved, and consequently not accessible for future use. Lastly, poor organizational memory results in that people in need of information do not know of the existence or who in the organization that possesses the relevant knowledge or information (Huber, 1991). Consequently, when an operating unit is in need of knowledge or a new technology that is already developed, they may not know where in the organization such exist.

In conclusion, organizational learning can be understood as driven by a wide a range of processes in the organization leading to an increase in knowledge. It should be noted that the processes reviewed does not have to happen in a specific sequence in the organization. It is more the case that these processes happen in parallel.

2.3 Organizational Structure

As highlighted by the research question, the purpose of this thesis is to study the structural influences on organizational learning. As with organizational learning, organizational structure is an extensive field of research in its own. It is therefore necessary to go through central literature within the field. This section will start with a general definition of organizational structure, and develop an argument that differentiation and integration are two fundamental concepts of organizational structure. Then, both differentiation and integration will be reviewed separately, in relation to introduction of new technology. Next, we will address literature that has considered the influence of structure on organizational learning. Lastly, we will review a body of literature that specifically address the issues of differentiation and integration with respect to the structuring of R&D.

2.3.1 Definition of Organizational Structure

A common, and agreed upon, understanding of organizational structure is that it is fundamentally concerned with the division of labor into distinct tasks, and consequently the coordination of these tasks (Mintzberg, 1983). Labor is divided into smaller tasks to allow subunits and their workers to specialize in completing these tasks. As labor is divided among subunits it becomes important to integrate the subunits into a coherent whole for the organization to achieve its overall goals. A definition of organizational structure that incorporates these issues is given by Child (1977, as in Daft and Lengel, 1986):

> Organization structure is the allocation of tasks and responsibilities to individuals and groups within the organization, and the design

> of systems to ensure effective communication and integration of effort (p. 559).

Thus, as suggested by Daft et al. (2010), organizational structure can be seen as intended to accomplish two thing: "It seeks to provide a framework of responsibilities, reporting relationships and groupings, and it is intended to provide mechanisms for linking and coordinating organizational elements into a coherent whole" (p.128).

These two purposes correspond to the concepts of differentiation and integration, respectively (Lawrence and Lorsch, 1967). Differentiation is concerned with how the work in the organization should be divided. Integration, on the other hand, is concerned with how the divided parts of the organization should collaborate in order to achieve the overall goals of the organization. There seems to be an agreement among researchers that achieving both differentiation and integration simultaneously is difficult, if at all possible. Lawrence and Lorsch (1967) showed an inverse relationship between differentiation and integration. Galbraith (1974) argues that there is a tension between differentiation and integration, and consequently that the purpose of the organizational structure is to manage this tension.

Thus, in order to develop our analysis of the structural influence on organizational learning it is necessary to review what is known about differentiation and integration, and the tension between them.

2.3.2 Differentiation

Definitions of differentiation found in the literature on organizational structure all seem to agree on the definition first set forth by Lawrence and Lorsch (1967):

> Differentiation is (...) the state of segmentation of the organizational system into subsystems, each which tends to develop particular attributes in relation to the requirements posed by its relevant external environment (pp. 3-4).

The main argument for organizations to divide their labor is that it allows the organization to specialize its jobs. Mintzberg (1983) argues that job specialization leads to improved skills of an individual as he or she specializes in one or few tasks, and a more optimal use of time since switching costs are significantly reduced. As a result, the productivity of the overall organization increases. Thus, the goal of differentiation is to structure the organization in such a way that each unit is optimally organized to perform its task(s). In relation to the introduction of new technology, two types of specialization in the organization is of particular interest. First is the specialization in tasks related to development of technology, and second is the specialization in tasks related to the operation of the production system constituted by technological artefacts.

The question that arises next is how these specialized positions should be grouped into units. According to Mintzberg (1983), it is through the process of grouping the specialized positions “into units that the system of formal authority is established and the hierarchy of the organization is built” (p. 45). The differentiated units are built through a process of successive clustering. First, individual positions are grouped into units. Second, these units are grouped into larger units, which again is grouped into an even larger unit, until the entire organization is contained in one, final unit. There are various bases for grouping; knowledge, function, output, client, time and place (Mintzberg, 1983). In relation to introduction of new technology two groupings are particularly relevant. First is the grouping of those tasks specialized in development of technology into separate R&D units. Second is the grouping of those tasks specialized in operating the production system into separate operating units. These two groupings are examples of functional grouping, as the positions are grouped according to the functions it uses to produce its products and services (Mintzberg, 1983). However, within operations, units are grouped on the basis of processes the workers perform. According to Mintzberg (1983) the technical system in operation often serve as the basis for process grouping.

Differentiation encourages strong coordination of work within each unit through direct supervision and informal contact (Mintzberg, 1983). Direct supervision is a result of having one manager for each unit. By letting one person be responsible for the work of others and monitor their actions, coordination within the unit is achieved. Members of the same unit often have to share the same resources, which encourages frequent informal contact between members of the unit (Mintzberg, 1983). This coordinating mechanism is referred to as mutual adjustment by Mintzberg.

For the same reasons as differentiation encourages strong coordination within a unit, it makes it challenging to achieve coordination between units. Since the communication is focused within the unit, differentiation isolates the members of different units from each other (Mintzberg, 1983). A central piece of Lawrence and Lorsch’s (1967) definition of differentiation is that each subsystem, or unit in the organization, develops certain characteristics related to its external environment. Lawrence and Lorsch (1967) found that the units became differentiated from each other in terms of their goals, time perspective, interpersonal styles of interaction and degree of formalization of their structure.

An implication of this is that having functionally differentiated operation and R&D units may cause challenges. While the production unit often have a goal of efficiency, a short time perspective, focus on getting the job done, and a bureaucratic structure, the R&D unit often have the completely opposite characteristic in all four dimensions. Being this fundamentally different may cause each of the two units to become even more narrowly focused on their own problems, and at the same time distancing themselves even further away from the rest of the organization (Mintzberg, 1983).

Taking the exploration and exploitation perspective on organizational learning developed by March (1991) may provide some insight in the benefit of differentiated R&D and operations. With a focus on efficiency and short time perspective operations are primarily doing exploitation. R&D, on the other hand, with a longer time perspective and the possibility to pursue uncertain technological opportunities are primarily doing exploration. Thus, this functional grouping may allow the organization to maintain a balance between these two learning activities, which according to March (1991) is important for organizational survival and prosperity.

Nevertheless, an important weakness of the functional structure is that it lacks a mechanism for horizontal coordination (Mintzberg, 1983). Therefore, a need to integrate the units across the organization arises.

2.3.3 Integration

Similar to differentiation there is an agreed upon definition of integration, here given by Lawrence and Lorsch (1967):

> Integration is (. . .) the process of achieving unity of effort among the various subsystems in the accomplishment of the organization's task (p. 4).

As discussed in the previous section, the organization is differentiated into a set of subunits in order to become experts in their respective areas. Given that the organization's goals cannot be achieved by the work done by each subunit alone, the work has to be put together, i.e. integrated. Introduction of new technology is an example of a task that requires joint effort from differentiated units, as it requires technology developed by the R&D unit to be implemented in operations. From the definition above, integration requires coordination across the different units in the organization. The goal of this coordination is to link the differentiated subsystems into a coherent whole such that the organization is able to achieve its strategies and goals (Daft et al., 2010).

While the need to integrate seems evident, how to do it in practice is not as clear, and therefore, several streams of research seek to answer this question. In the terms of Lawrence and Lorsch (1967), integration is a matter of employing a number of positions in the organization, specifically designed to coordinate the work of different subunits. However, another stream of research that provide valuable insight is the discussion of different coordination mechanisms employed by the organization to govern collaboration between its units; price, authority and trust (e.g. Bradach and Eccles, 1989; Adler, 2001). This discussion is on another level of analysis than the integrative positions implied by Lawrence and Lorsch (1967) because it considers overall policies in the organization, as opposed to specific roles and individuals. Nevertheless, it provides valuable insight on how the organization can achieve unity of effort among its subsystems, and is therefore considered as a matter of integration. Both streams of research will be reviewed in the following two sub sections.

2.3.3.1 Integrative Positions: Liaison Positions and Integrating Managers

When introducing new technology in operations a collaboration between R&D and operations is necessary. The tasks performed by the two differentiated units depend on each other, and thus a type of integration referred to as requisite integration arises (Lawrence and Lorsch, 1967). Technology developed by R&D must be fit with the existing production system in operations. This requires a coordinated effort from both units. Thus, in order for new technology to be successfully put to use, the two units have to be highly integrated. But at the same time they are highly differentiated, one performs research, the other performs operating tasks. As discussed above, coordination among units become more difficult when they are highly differentiated. However, that is not to say that it becomes impossible.

Lawrence and Lorsch (1967) argue that integrative positions tend to emerge in environments characterized by a high degree of both differentiation and integration. When introducing new technology in a production system that already contains several other technologies a large amount of direct contact between R&D and operations is necessary in order to coordinate the work of the two units. Mintzberg (1983) presents several integrative devices, two of which serve this specific purpose: liaison positions and integrating managers. Establishing both of these integrative positions leads to a formalized coordination of the two units (Mintzberg, 1983). Thus, leading to a more predictable organizational behavior.

A liaison position is needed when a considerable amount of contact between the two units is necessary to coordinate the work of the two units. The responsibility of the liaison person is to formally route the communication directly between the two units, bypassing the vertical channels (Mintzberg, 1983). Even though this person does not have any formal authority, he or she has informal power over the decision processes that affect the two units due to the knowledge this person possesses. This knowledge partly comes as a result of the person being the centerpiece of communication between the two units. The integrating manager is needed when more coordination by mutual adjustment between the two units is needed than what a liaison position provides. The integrating manager has the same responsibility as the liaison person, but in contrast has some formal authority over the decision processes between the two units (Mintzberg, 1983). It is important to notice that an integrating manager does not have any formal authority over the personnel in the units.

There is also a difference between the structural design of liaison positions and integrating managers. A liaison person is located in one of the two units, but with the role to communicate and achieve coordination with the other units (Mintzberg, 1983). An integrating manager on the other hand, is according to Mintzberg (1983), located outside the units, and given some of the power that previously was in the two separate units.

2.3.3.2 Coordination Mechanisms: Price, Authority and Trust

As suggested above the question of how to integrate and coordinate a differentiated organization can also be viewed as a question of how to employ the coordination mechanisms authority, price and trust. This question has been the origin of a substantial area of research and debate, which also extends to inter organizational coordination (e.g. Ouchi, 1980; Bradach and Eccles, 1989; Adler, 2001). Here we will focus primarily on the role of these coordination mechanisms as means of coordination within the organization.

Alone, each of the coordination mechanisms lead to different forms of organization. Authority leads to a hierarchical form of organization, while price leads to a market-based form of organization. Trust is the basis for a community- or clan-driven form of organization. In practice, organizations typically employ a combination of these. Adler (2001) discusses each of these forms with respect to knowledge-based assets in the organization. As showed earlier, knowledge plays a particularly important role in organizational learning, thus understanding how the different coordination mechanisms treats knowledge is interesting. Adler's (2001) discussion will therefore be reviewed in some detail.

In a hierarchical organization authority is used to control the vertical and horizontal division of labor. A hierarchical organization relies to a great extent on centralized authority. This enables the top of the organization to enforce collaboration between the divisions and between the divisions and the headquarter. Adler (2001) argues that this organization form, while efficient at routine-tasks, struggle with non-routine task, simply because such tasks cannot be commanded by the hierarchy. Thus, sole reliance on authority as a coordination mechanism creates little opportunity for generation of new knowledge because that would require non-routine actions (Adler, 2001).

Market as an organization form relies on price as a coordination mechanism. This means that the organization's own units are treated as autonomous profit centers, and they charge each other for their product or services – similar to an actual market. However, while it provides incentives for units to create knowledge, the market organization will fail to allocate knowledge optimally (Adler, 2001). Because knowledge is not depleted when used, optimal allocation would only happen if everyone were given free access to it.

Thus, while the hierarchy can command optimal allocation of knowledge, it does not create strong incentives for generating it. Market, on the other hand is successful in creating strong incentives for knowledge generation, but leads to suboptimal allocation of knowledge. Instead of sufficing with a suboptimal solution, Adler (2001) proposes that bringing trust into the mix can improve the generation and allocation of knowledge. As a third coordination mechanism, trust should be combined in varying degrees with price and authority.

In combination with hierarchy, trust can lead to a more enabling form of hierarchy, referred to as an enabling bureaucracy (Adler and Borys, 1996). In these organizations, formalized and standardized procedures are often defined jointly between managers and employees (Adler et al., 1999), leading to more enabling procedures allowing the employees to perform their jobs more effectively and reinforce their commitment (Adler and Borys, 1996). "The enabling approach requires and encourages a reduction in disparities of power, knowledge, skills and rewards between managers and subordinates" (Adler and Borys, 1996, p. 81). This stands in contrast to the coercive form of bureaucracy, where employees are enforced to adhere to standards, which may appear in the absences of trust.

Together with price, trust can create relational contracts, reducing the associated transaction costs and risks of agency problems (Adler, 2001). Trust reduces transaction cost by replacing contracts with handshakes and agency problems by letting mutual trust replace the fear of shirking and misrepresentations (Adler, 2001). Moreover, if trust and an underlying sense of community is present in price negotiations, the chance increase for an outcome that is beneficial for both parties.

However, trust also has its challenges. Adler (2001) points out that trust risk creating closed communities within the organization with little willingness to accept external input. Thus, it is important not to rely on trust alone. Both hierarchy and market can function as correction of such tendencies (Adler, 2001). Thus, in terms of integration the organization should employ a mix of authority, price and trust mechanisms to facilitate how the differentiated units coordinate their work.

2.3.4 Influence of Organic and Mechanistic Structure

In the innovation literature a prevalent view has been that an organic structure is much more effective at facilitating innovation than a mechanistic structure. While this idea was originally developed in the work of Burns and Stalker (1961), the ideas are still held by many researchers today (Trott, 2008). The mechanistic structure is characterized by specialized differentiation of functional tasks, high degree of formalization and standardization, and a hierarchic structure of authority, communication and control (Burns and Stalker, 1961). It is therefore argued to be best fit for stable environments and programmable tasks. In contrast, organic structure is best suited to changing conditions, and is characterized by low formalization, and a network structure of authority, communication and control (Burns and Stalker, 1961).

Interestingly, it seems that this view has been directly adopted by researchers on organizational learning. Within this field it is argued that to enhance organizational learning, organizations should move away from a mechanistic structure and towards an organic structure (Fiol and Lyles, 1985). In fact, Meyer (1982) has suggested that "formalized and complex structures retard learning but that learning is enhanced by structures that diffuse decision influence" (p. 533). Thus, organizations are encouraged to move away from formalized and complex structures, and towards a structure that is more decentralized and allows a higher degree of autonomy (Fiol and Lyles, 1985; Meyer, 1982)

While Burns and Stalker's (1961) position has been subject to critique within the innovation field (Trott, 2008), the same ideas seems largely uncriticized within organizational learning. In relation to technology introduction this poses an interesting problem. Developing, transferring and integrating technology on a large scale depend on teams of researchers, as well as a formalized coordination with the operating units. Therefore, an informal structure is largely infeasible. Thus, it seems reasonable to question whether reducing formalization is necessarily beneficial for all learning processes. Specifically the ones that occur during technology introduction.

2.3.5 Effective Structuring of R&D

As we have discussed earlier, the R&D unit plays an important role during introduction of new technology. Therefore, the structuring of the R&D unit is of particular interest. Several researchers have looked into the issues of whether the R&D unit should be centralized or decentralized, and how to integrate the R&D unit with the operating units (e.g. Coombs, 1996; Hill et al., 2000).

Coombs (1996) presents three paradigms of how to organize the R&D unit. The first paradigm is concerned with centralization of the R&D unit, and the corporate dominance of the funding, ownership and control of the R&D unit. In later years, the focus shifted to a more market-driven R&D organization, which is the focus in the second paradigm. With the market-driven philosophy comes the decentralization of the R&D unit, and the funding, ownership and control over the R&D unit is in the hand of the operating units. The third paradigm aims at combining the benefits from each of the first two paradigms. Therefore, the control, funding and ownership of the R&D unit is shared between the corporate core and the operating units.

According to Coombs (1996) there was a shift from a bureaucratic organization of the R&D unit to a more market-driven organization during the 1970s and 1980s. Hill et al. (2000) argue that internal markets act as an additional mechanism for coordination between the units in the organization, as well as it is "a surrogate for the discipline of the external market" (p. 564). Therefore, the R&D unit was integrated into the strategies of the operating units it served (Coombs, 1996). This led to a shift in the funding of the R&D unit, from corporate to the operating units. Another advantage of a decentralized R&D unit is that it allows a closer relationship between the R&D unit and the operating unit to develop. In this way the technical expertise is combined with the operating knowledge in effective teams.

However, there are some drawbacks with decentralizing the R&D unit. A decentralized R&D unit is good at strengthening the existing technological regime. This becomes problematic if the technological regime of the organization becomes less competitive. With a decentralized R&D unit, the R&D may, in such a case, "run the risk of digging a deeper hole for the company" (Coombs, 1996, p. 347). Second, a too close integration of the R&D unit with the operating unit will make it prioritize close-to-market product development (Hill et al., 2000). When the R&D unit uses market relations within the organization, the unit runs the risk of letting the short-term perspective replace the long-term research (Hill et al., 2000). There are two reasons to why this shifts takes place with a decentralized R&D unit. First, the customers are not willing to pay for anything more than their immediate requirements. And second, an R&D unit organized as an independent profit center will be incentivized to prioritize activities that pay off as close in time as possible (Hill et al., 2000).

Coombs (1996) argues that by combining some of the characteristics with the bureaucratic organization of the R&D unit with the market-driven organization, the challenges described above can be mitigated. Letting some of the control and ownership over the technological regime be in the hands of the corporate part of the organization, the technical competences and the R&D capacity will generally be oriented to longer term strategic research (Coombs, 1996). Thus, helping the organization avoid being trapped with useless technology. Next, Coombs (1996) argues that it is important to keep the R&D unit at arms-length from the operating units in order to insulate them from the short term pressure in operations. A way to achieve a longer time perspective, in at least parts of the R&D unit, is to ensure that parts of the funding of the R&D unit comes from the corporate parts of the organization. Lastly, Coombs (1996) argues that it is important to have a corporate unit for the strategic management of the technology. The function of this unit should be to analyze the structure of the overall technology portfolio, ensure that technological competences in one operating unit is known to and available to other units where the competence is relevant, and to manage the technology portfolio.

Methodology 3

In the following subsections the research methodology adapted in this thesis is made visible to the reader. First, the choice of research strategy is explained. Second, the research design is described. Third, the research method used for data collection is presented in detail. Lastly, the approach used for data analysis is described.

3.1 Research Strategy

As outlined, the aim of this thesis is to contribute to the understanding of the influence of organizational structure on organizational learning during technology introduction. This aim was captured by formulating the aforementioned research question. To best address the research question a qualitative research strategy was chosen. Several properties of qualitative data are specifically beneficial for our research. First, qualitative research provides rich and nuanced data, which helps to understand the rationale behind human actions. Second, qualitative data allows a deep understanding of the complex processes that drives organizational learning.

As the research question indicates, this thesis aims to understand *how* organizational learning take place during technology introduction, and *how* it is influenced by the organizational structure. Inherent in these questions is the need to understand *why* organizational members takes the actions that they do. Understanding the rationale behind their actions would help us understand how these actions are influenced by the organizational structure. This focus on “seeing through the eyes” of the research subjects is more in line with a qualitative approach (Bryman, 2012). In particular, the tendency of qualitative research to produce rich and contextual data is useful for this purpose.

Furthermore, as discussed in section 2.2 Organizational Learning, organi-

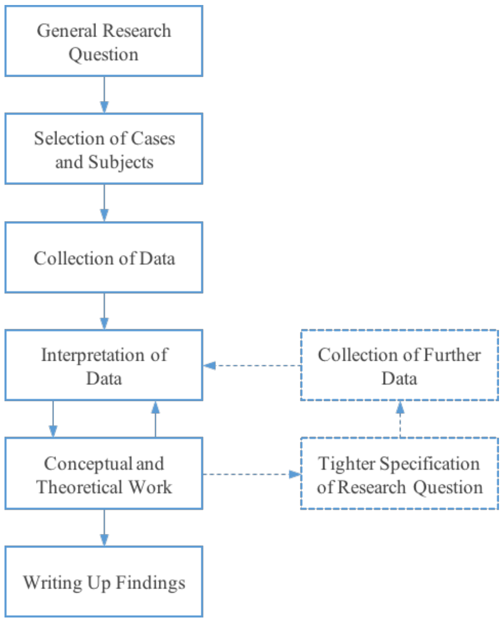

Figure 3.1: Main Steps in Qualitative Research (Bryman, 2012, p. 384)

zational learning is driven by a set of processes. Graebner et al. (2012) argue that qualitative data is effective towards understanding complex process issues:

> The fundamental advantage of qualitative data for investigating process phenomena is its richness, which enables researchers to unpack multifaceted, temporally unfolding situations and causal mechanisms in a detailed and sophisticated manner (p. 279).

Therefore, collecting rich qualitative data will allow us to understand the organizational learning processes that takes place in the organization during introduction of new technology.

Thus, the following sections will outline the research design and method that were employed to carry out a qualitative study. An overview of the qualitative research approach is given in figure 3.1.

3.2 Research Design

The choice of research strategy is only the first step towards building a research methodology. While it does lay out the general goals for the research and set some guidelines for what should be the primary focus, it does not provide any practical advice as to how to actually conduct the research. The research design, on the other hand, provides "a framework for the collection and analysis of data" (Bryman, 2012, p. 46). For this thesis a comparative case-study design has been chosen. In this section the reasons for, and effects of this design will be described.

The reason for choosing case study, is to a large extent overlapping with the earlier presented arguments for choosing a qualitative approach. First, the case study is argued to be particularly appropriate when prior theory is lacking or underdeveloped. Eisenhardt (1989) makes a widely cited description of theory building from case study research and concludes: “In sum, theory building from case studies is most appropriate in the early stages of research on a topic or to provide freshness in perspective to an already researched topic” (p. 548).

Thus, given our goal of contributing to the underdeveloped theory in the intersection of organizational learning and organizational structure, a case study research should be appropriate.

Second, according to Yin (2009) the case study is suitable if the research question seeks to explain how or why a social phenomenon works. Moreover, he argues that: “The distinctive need for case studies arises out of the desire to understand complex social phenomena” (Yin, 2009, p. 4). This is well in line with our goal of understanding how the organizational structure influences the organizational learning processes.

Due to it’s tight link to the data, the resultant theory from case studies is often empirically valid (Eisenhardt, 1989). However, a weakness with case studies is that its tight link to empirical data can lead to the creation of highly complex theory, with much details but little overall perspective (Eisenhardt, 1989). This is a concern that has to be carefully managed in the data analysis process.

While a common argument against case studies is that the process is biased by researchers’ preconceptions, Eisenhardt (1989) argues that the inherent process of comparing cases, and cases with literature has the benefit of forcing the researcher to rethink his developing theories. “This constant juxtapositioning of conflicting realities tends to “unfreeze” thinking, and so the process has the potential to generate theory with less researcher bias than theory built from incremental studies or armchair, axiomatic deduction” (pp. 546-547). While a compelling argument, it is important to note that achieving this in practice necessitate active comparison in the analysis process. Important in this respect is whether more than one case is used.

An important distinction exists between the use of single and multiple cases. Yin (2009) notes that in some fields, researchers consider the two as different methodologies, but he considers them to be two variations of the same research design. Still he suggests that: “Multiple-case designs have distinct advantages and disadvantages in comparison to single-case designs” (Yin, 2009, p. 53). Citing Herriott and Firestone (1983, as in Yin, 2009) he notes that evidence resulting from multiple cases is often considered more compelling, and consequently such studies are regarded as being more robust. However, conducting multiple-case studies require extensive resources, and is not a task to be taken lightly.

Regarding the number of cases used, it is important to note that the analytical power of multiple cases in qualitative research comes from a *replication logic*, rather than a *sampling logic* (Yin, 2009). In other words, the number of cases is not important to achieve statistical significance as with quantitative research. Instead, it is a matter of comparing and studying a social phenomenon in different situations and contexts in order to widen our understanding of it. The practical implication of this is that having more cases is not necessarily better if it comes at the cost of how good each case is analyzed and understood in its own.In this thesis two cases of technology introduction, within one case company, have been used. This decision can be seen as a matter of resource optimization. Given the constraints inherent in a master thesis, taking on too many cases could easily come at the cost of the depth at which each case is analyzed. However, as highlighted above, it is possible to achieve substantial analytical depth and robustness through comparison of cases. Thus, the marginal value of increasing from one to two cases were considered so large that it outweighs the potential loss in depth of each case separately. It should be noted that the case company did provide access to additional relevant cases, so the decision not to add further cases is not a matter of "convenience sampling", but rather an active decision to get the best analytical depth and robustness given our available resources.

Lastly, another consideration that should be reflected upon is the distinction between intrinsic and instrumental case study (Stake, 2005). In an instrumental case study, the goal is to understand and illustrate a general phenomenon that is true across different cases. In contrast, the intention of the intrinsic case study is simply to understand that particular case.

The primary goal of this thesis is to answer the research question. As the reader may have noted, the research question is general in nature, i.e. case-independent. This means that we seek to generalize our findings to a more widely valid theory. Setting this purpose highest makes our case study instrumental. The within-case analyses seek to understand how the structure influences learning in those particular cases. The cross-case analysis and discussion, on the other hand, seek to generalize from these findings and contribute to theory by nuancing the existing literature.

An important implication of doing an instrumental case study is that both cases and informants should be chosen with the research question in mind. The process of sampling will be covered in the next section.

3.3 Research Method

Research method is the technique(s) used for collection of data. According to Bryman (2012) interviews are probably the most widely used method to collect data in qualitative research. Yin (2009) argues that interviews are an essential source of evidence in case studies. The greatest advantage of interviews is the flexibility they offer. It gives the researchers the ability to follow the direction in which the interviewees take the interview. As the interest is to understand the interviewee's point of view in qualitative research, the rich and detailed answers the interview offers are of great interest.

The qualitative interview is either unstructured or semi-structured. In this research semi-structured interviews were used, as this allows the informant to bring up what he or she believe is important, as well as it offers flexibility during the interview to ask questions that are not included in the interview guide (Bryman, 2012). Moreover, it allows the interviewee to speak freely and elaborate about the topics discussed. This provides rich and detailed data, allowing us to devise thick descriptions of the situations studied. The choice of using semi-structured interviews instead of unstructured interviews is that the semi-structured interview gives some structure, which ensures that the same topics are discussed with all informants. This helps to make sure that all perspectives of the situations are captured.

In order to answer the research question it was important that the sample chosen was relevant for the research question posed. Sampling involves both the selection of cases and participants within the cases. We have used a purposive sampling technique, which is a non-probability form of sampling. The goal of purposive sampling is to sample cases and participants in a strategic way, so that those sampled are relevant to the research questions that are being posed. In other words, the cases and participants are selected because of their relevance to the research question (Bryman, 2012).

The sampling criteria for the cases was that they were related to the introduction of new technology in the case company. When it comes to sampling of participants a combination of purposive sampling and snowball sampling was employed. Snowball sampling is, according to Bryman (2012), "a sampling technique in which the researcher samples initially a small group of people relevant to the research questions, and these sampled participants propose other participants who have had the experience or characteristics relevant to the research" (p. 424). Therefore, we initially contacted people that played a key role in the technology introduction cases. One for each case. Next, we let them propose other participants who, according to them, were important during the introduction of the new technology.

It can be argued that the participants who were initially contacted served as key informants. According to Yin (2009), "key informants are often critical to the success of a case study" (p. 107). In addition to providing insight into the case, they can also give access to other sources of data, such as documents, which can serve as a contrary or confirmatory source of evidence. Key informants can be of great help, but as both Bryman (2012) and Yin (2009) highlight, one has to be cautious about relying too much on them. Having an undue reliance on key informants, the researchers risk seeing the social reality through the eyes of one, or few, members of the social setting, instead of seeing the reality through the eyes of all the members. As a result, the researchers will not get a nuanced picture of the reality (Bryman, 2012).

To counter this potential bias, a broad range of people were interviewed in both cases, spanning from researchers, to unit managers, to technical managers, to operators. This was done in order to make sure that all perspectives on the cases were covered, because lacking some perspectives would have reduced the validity of the study (Tjora, 2012).

In addition to interviews we have used company presentations and internal documents as a form of triangulation to cross check the findings (Bryman, 2012). The advantage of employing multiple sources of evidence in case studies is the development of *converging line of inquiry* (Yin, 2009). This means that the findings from the case study are more likely to be accurate and convincing.

Table 3.1: Overview of Informants: Anode Recipe Project

Unit	Informant	Duration (Min)
Sunndal Carbon	Unit Manager	55
Sunndal Carbon	Area Manager	51
Sunndal Carbon	Technical Manager 1	71
Sunndal Carbon	Technical Manager 2	43
Sunndal Carbon	Operator 1	48
Sunndal Electrolysis	Technical Manager 3	49
PMT	Single Point of Contact	89
PMS	Governance Manager**	83

Table 3.2: Overview of Informants: Emulsion Project

Unit	Informant	Duration (Min)
Karmøy Wire Rod	Unit Manager	59
Karmøy Wire Rod	Technical Manager 1	58
Karmøy Wire Rod	Technical Manager 2	58
Karmøy Wire Rod	Operator 1	47
Karmøy Wire Rod	Operator 2	42
Karmøy Wire Rod	Operator 3	32
Karmøy Wire Rod	Operator 4	31
Karmøy Administration	Procurement Manager*	36
Casthouse Support	Project Manager*	42
R&D Bonn	Senior Researcher*	38

Table 3.1 and table 3.2 give an overview of the sampled participants who were interviewed. The tables include information about the unit the informants belonged to, their position in the company and the duration of the interview. In total 18 interviews were conducted, eight informants were interviewed in the Anode Recipe Project, and ten informants were interviewed in the Emulsion

Project. Most of the interviews were conducted on-site, at the production plants, but three of the interviews were conducted over the phone. These interviews are marked with a star (*). The interview marked with a double star (**) was conducted by a fellow master's student at NTNU, with whom we collaborated on the data collection process.

As the tables show, the informants interviewed were from different units and functional areas in the case company. Interviewing informants with different perspectives on the case as well as using documents allowed us to get a more nuanced perspective of the processes that took place in each case.

Saturation is an important criterion in order to determine when to stop with the interviews (Bryman, 2012; Tjora, 2012). Bryman (2012) argues:

> Saturation does not mean, as is sometimes suggested, that the researcher develops a sense of déjà vu when listening to what people say in interviews, but that new data no longer suggest new insights into an emergent theory or no longer suggest new dimensions of theoretical categories (p. 421).

Based on this criterion, sufficient data was collected after the first round of interviews in the anode recipe case. In the emulsion case, three follow-up interviews were conducted with operators to get a more nuanced perspective on the the technology integration process.

3.4 Data Analysis

After collecting all the data, interpretation of data is the next step in the qualitative research process, as shown by figure 3.1. The purpose of data analysis is to reduce the amount of data, relate the research to the literature, and to present the results of the research to others (Bryman, 2012).

In relation to data analysis the two concepts inductive and deductive are often used to describe the relationship between theory and research (Bryman, 2012; Tjora, 2012). Letting theory guide the research is referred to as a deductive approach. If theory is the outcome of the research, an inductive approach is taken (Bryman, 2012). In this research we have had an approach to data analysis similar to Tjora's (2012) *stepwise-deductive inductive (SDI) model*. The essential premise for the SDI model is a consistent inductively driven curiosity. However, as both organizational learning and organizational structure are well developed fields of research, general topics and issues are already well known. Thus, while our analysis of data is inductively driven, it is also bounded by a frame of reference from existing theory. The model is illustrated in figure 3.2 and consists of different stages from raw data to concepts or theory. The upward process represents the inductive part of the research, while the downward process represents the deductive approach, the connection of theory to the empirical findings (Bryman, 2012).

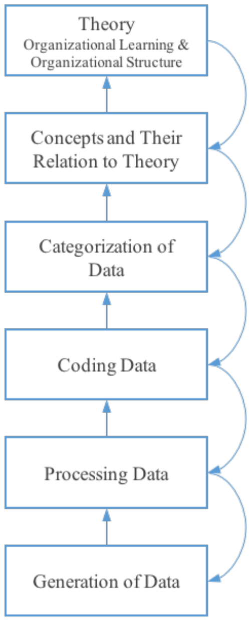

FIGURE 3.2: Main Steps in Data Analysis (Adapted from Tjora, 2012, p. 175)

The starting point of the data analysis is to code the raw data. The codes should be induced from data, and not from theory or the research question. This was done by assigning describing words or phrases to each paragraph or small segments in the data material. Tjora (2012) recommends to work as closely to the empirical data as possible when coding. In this way, the codes that emerge are as tightly linked to the data as possible, which is the ultimate goal. According to Tjora (2012), a determinant of good inductive SDI coding is whether the codes could have been determined a priori to the research, or if they can only be derived from the empirical data.

The next step in the SDI model is the categorization of the data. This was done by gathering the relevant codes in groups. In this step it is no longer the data that should be the prime driver, but the research question (Tjora, 2012). Based on the research question the relevant codes were grouped together. According to Tjora (2012) the categories should form the basis for the main topics in the analysis.

So far, the steps in the model has been tightly coupled to the empirical data. When moving to concepts theory becomes more important. It is during this step the categories from the previous step is considered in light of theory. The purpose is to understand if the categories are related to existing theory within the field (Tjora, 2012).

The last step in the SDI model is to contribute to theory. However, for smaller research projects in qualitative research this does not necessarily mean development of new theory, but rather about conceptual generalization (Tjora, 2012). This means to describe the findings in terms of models, typologies or concepts that are not tied to the specific empirical data used in the research (Tjora, 2012).

As described earlier, we have used a two-case design for the collection of data. When it comes to data analysis, the cases can be analyzed separately, referred to as within-case analysis, and across, referred to as cross-case analysis. Eisenhardt (1989) discusses within-case and cross-case analysis in some detail. The goal of within-case analysis "is to become intimately familiar with each case as a standalone entity" (Eisenhardt, 1989, p. 540). Through this process the researcher allows time for the particularities of each case to emerge, before rushing to do a cross-case comparison. When ultimately moving to the cross-case analysis, it is important not to jump to premature or false conclusions. Eisenhardt (1989) suggests using structured and diverse ways to analyze the data, in order to force the researcher to go beyond the initial impressions.

Case Studies 4

The aim of this chapter is to answer the proposed research question by presenting and analyzing empirical data. First the case company will be presented, then each case will be described and analyzed separately. Each within-case analysis will be split into two. First, the analysis focuses on developing an understanding of the organizational learning that takes place during the introduction of new technology in the respective case. Second, the structural elements that were found to influence this organizational learning process are analyzed. Lastly, a cross-case analysis is carried out.

4.1 Introduction to Case Company

The case company in this thesis is Norsk Hydro ASA, referred to as Hydro. Hydro is a large aluminium company with activities throughout the value chain. The company is based in Norway, but has global presence, with a total of 13,000 employees worldwide.

An overview of the main steps involved in the production of primary aluminium is shown in Figure 4.1. The production of aluminium takes place in large production systems. Through the smelting process in the electrolysis, alumina is transformed into aluminium. In addition to refined alumina, this process requires anodes, cathodes and electricity. The electrolysis process requires very high current, typically around 200,000 amperes. The electric current flows between a carbon anode and a cathode, which is part of the electrolysis cell. While the electrochemical principles are relatively simple, producing aluminum on a large industrial scale is highly complex. Each step in the process is highly interdependent and configured in relation to each other. Therefore, changing the technology in one step of the process has implications for the steps before and after.

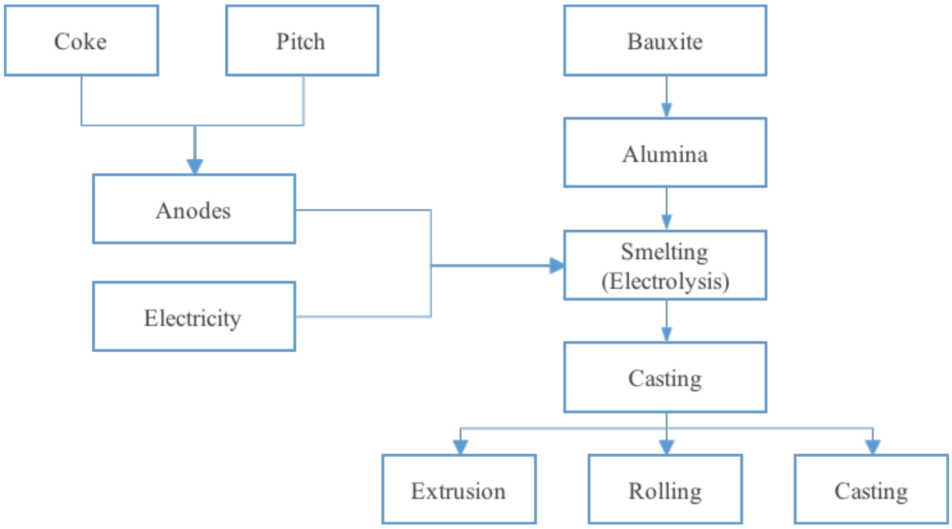

Figure 4.1: Value Chain of Primary Metal

Hydro's corporate structure is designed according to the value chain of aluminum, and consists of four main divisions: *Bauxite and Alumina*, *Primary Metal*, *Rolled Products*, and *Energy*. The empirical data collected in this thesis was primarily from the Primary Metal division. Within this division the focus was mainly on *Global Fully-Owned Smelters* (GFOS). All of the five smelters within GFOS, hereby referred to as plants, are located at different geographical sites. Each of the plants are organized as separate profit centers.

The two cases consider two different projects where new technology was introduced in two of the plants within GFOS: Sunndal and Karmøy. The first case, *anode recipe project*, involved technology from Primary Metal's own R&D unit, *Primary Metal Technology* (PMT). The second case, *emulsion project*, involved technology from an R&D unit within Rolled Products. Figure 4.2 outlines Hydro's organizational structure, and indicates the units that were relevant for the two cases.

The anode recipe project was centered around the anode production at the Sunndal plant. The anodes are, together with electricity, alumina and cathodes, the most important technological artefacts in the electrolysis process. In this case the anode recipe had to be modified as a result of cracks in the anodes when the current was increased in the electrolysis. Solving this problem involved both the carbon unit and the electrolysis unit. In addition, PMT was involved because a new recipe had to be developed.

The emulsion project was centered around the production of wire rod at the Karmøy plant. Wire rod is one of Hydro's end products. Production of wire rod is a special case because it involves both casting and rolling in one process. It is therefore dependent on an emulsion to lubricate, cool and clean the rolling mills. In this case the emulsion was replaced by a new type of

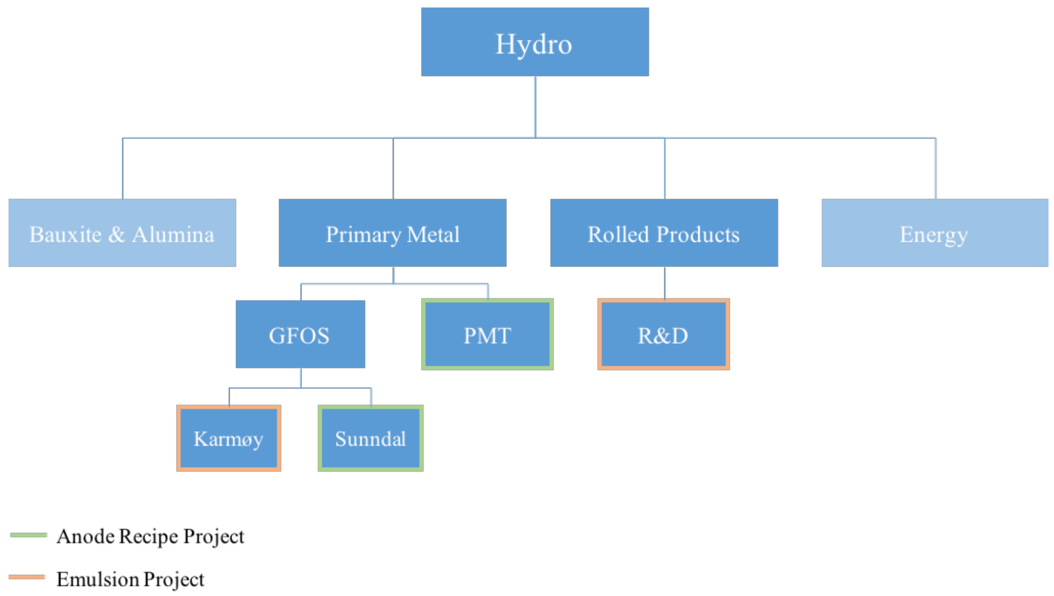

FIGURE 4.2: Hydro's Organizational Structure, Indicating the Units Relevant for the Studied Cases

emulsion, based on a different technological principle. The change was driven by *Health, Safety and Environment* (HSE) problems, high costs and instability in the production processes associated with the old emulsion technology. The project involved the wire rod casthouse at Karmøy and one of the research units within Rolled Products.

4.2 Within-Case Analysis: Anode Recipe Project

4.2.1 Introduction to the Case

Anodes are a critical component in the electrolysis process (see figure 4.1). Moreover, the anode is consumed in the process, and must therefore be replaced regularly. Each lasting only a limited number of days in production. Hydro produces a large portion of the anodes in-house, both at Sunndal and Årdal. However, they also purchase a significant portion of the anodes from an external supplier. This case is centered around the anode production in the carbon unit at Sunndal plant, which is a separate unit that reports directly to plant management. It will hereby be referred to as anode production. Immediately downstream to anode production is the electrolysis process, which is also organized as a separate unit, hereby referred to as electrolysis.

The anode recipe project was a project carried out to improve the quality

Figure 4.3: Timeline for the Anode Recipe Project

of anodes produced at Sunndal. It was a response to poor performance of the Sunndal anodes, relative to externally supplied anodes. The Sunndal anodes tended to crack more frequently in the electrolysis than its counterparts from other suppliers. The project itself lasted over a period of two years, from 2011 to 2013. It was preceded by a longer period of anode related problems in the electrolysis, that were ultimately traced to the Sunndal anodes. See figure 4.3 for an overview of central events before and during the project.

The project lead to a new anode recipe, and a corresponding change in the production process. The result was a significant improvement in performance. Figure 4.4 shows the performance of the anodes produced at Sunndal before and after the implementation of the new recipe. A stable, low value is desirable. As indicated by the figure, the anode production unit was able to produce anodes with higher and more stable performance after the project.

The project involved three organizational units within Primary Metal; Sunndal plant, PMT and *Performance Management System* (PMS). Figure 4.5 shows the relevant units, and the relation between them.

The technology unit, PMT, consists of three research centers, two of which are co-located with a plant and one in a separate location. This case involved personnel from two of these research units. PMT is partially funded through

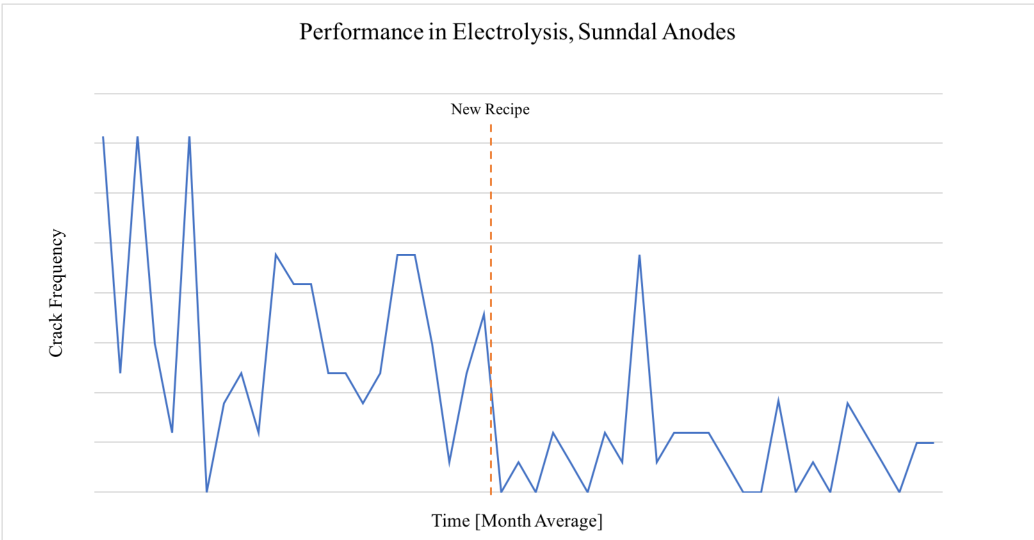

Figure 4.4: Performance of Sunndal Anodes Before and After New Recipe

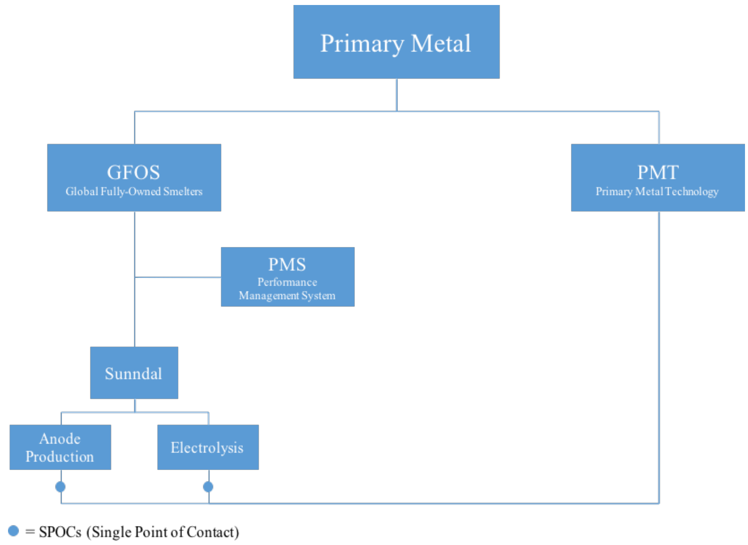

FIGURE 4.5: Overview of Organizational Units Relevant in Anode Recipe Project

corporate sources, and partially by conducting projects for the operational units. Because technology is primarily developed in PMT, but put to use in one (or several) of the plants, the management of the intersection between these two units is important for introduction of new technology. In order to handle this intersection Primary Metal has appointed a number of positions referred to as a *Single Point of Contact* (SPOC). Each plant has one SPOC for each business area within primary metal. For example, the Sunndal plant has two SPOCs; one for carbon and one for electrolysis. Lastly, PMS is responsible for the governance of technology improvement projects, and to link new technological solutions to problems in operations. Within Hydro this is referred to as a three-party cooperation, consisting of an operating unit, the research unit (PMT) and the governance function (PMS).

4.2.2 Organizational Learning During Introduction of New Technology

In this section, the empirical data from the anode recipe project will be presented as a narrative of the events that took place during introduction of new technology. The emphasis will be on the processes that contributed to organizational learning: identifying the problem, finding and developing a solution, and integrating new technology with existing machinery.

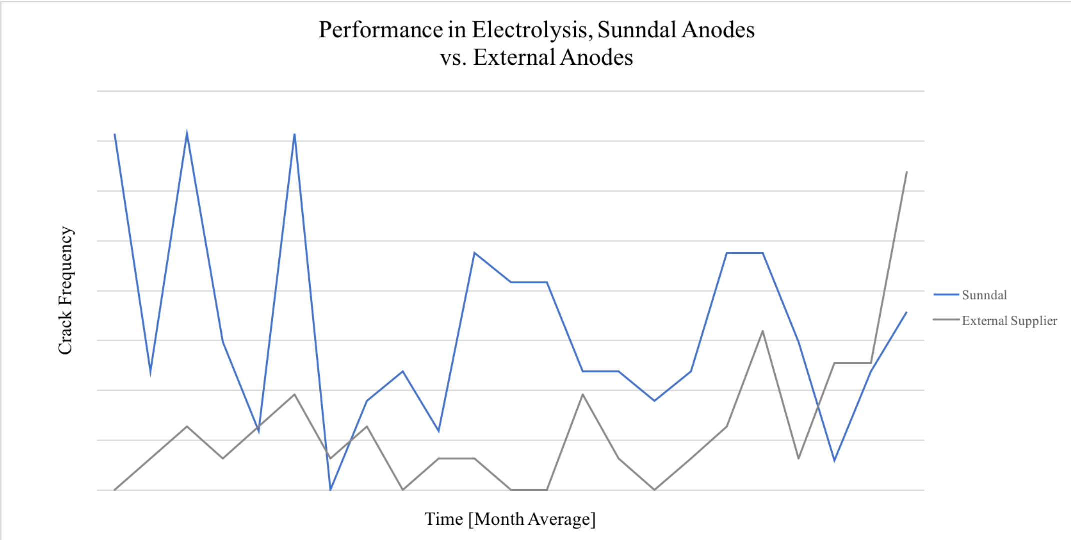

Figure 4.6: Performance of Sunndal Anodes Relative to External Anodes Before New Recipe

4.2.2.1 Identify Problem

As part of a continuous effort to increase the output from the electrolysis, the anodes were put under increasing pressure. During 2004 a problem started to occur; some of the anodes began to crack while in midst of production. The problem was not critical in the sense that production was stopped, but cracks in the anodes disturbed the heat balance of the electrolysis cells, and thereby significantly reduced the output of aluminium from the affected electrolysis cells. At this point the source of the problem was not clearly understood.

By 2007 the problems had not decreased, and the technical manager in the electrolysis decided to establish a portion of the electrolysis cells as reference cells in order to monitor anode performance more closely. In these cells the type of anode that goes in, and its performance was carefully measured and logged. From this information the electrolysis was able to track the performance of each anode supplier over time. Among several different performance indicators, one was the crack frequency. At this particular measure it appeared that the Sunndal anodes performed consistently worse than the external supplier (see figure 4.6).

The technical manager in the electrolysis highlighted the importance of measuring in order to track down the problems and raise these issues to the particular supplier.

> By separating the different anodes from each other, and monitor each anode type closely then you are able to tell that okay now it is actually that particular supplier that does not deliver. It is especially the anode cracks, and the performance of the electrolysis

> cells we follow up. And it is very easy for me to pick up the phone and call that particular supplier and tell them that their cells have had four times higher deviations than the other cells the last two weeks; now you have to figure out what is going on.
>
> Technical Manager 3, Electrolysis

Thus, after the problems started to occur, the very first step in the learning process was to become aware of the problem. And more importantly, not just that the problem occurred but why it occurred. Understanding why was therefore the first knowledge acquired in the process of solving the problem. This knowledge was acquired through careful measurements of the production process in the electrolysis, and those parameters that were believed to be relevant for the problem. From the viewpoint of the electrolysis, understanding why consisted of observing that certain anodes tended to crack, and then learning that this was related to one particular anode supplier; anode production at Sunndal.

However, when confronted by the electrolysis it was difficult for the anode production unit to acknowledge that the problem occurring in the electrolysis was due to a weakness in their anodes. This was mainly because they were not able to understand what was wrong.

> We could not understand that it was something wrong with the anodes. Before we delivered them [to the electrolysis], they looked perfectly fine. We did quality check that there were no cracks on the outside. (...) We thought that it was not our fault; the electrolysis gets perfect anodes, and then they destroy them for some reason.
>
> Technical Manager 1, Anode Production

What is interesting to note here is that through their own, internal quality checks they could not find anything wrong with the anodes. Therefore, it seemed reasonable from their point of view to conclude that the problem could not be caused in anode production. Thus, a situation occurred where the electrolysis was certain that the problems were caused by the Sunndal anodes, but anode production at Sunndal could not find anything wrong with their anodes. Consequently, over a period of several years the issue of anode quality was a recurring topic in the weekly anode meetings between anode production and the electrolysis, without any significant progress being made.

> It has been an issue every single week for many, many years, that the Sunndal anodes crack.
>
> Technical Manager 3, Electrolysis

Therefore, it seems evident from this case that effective problem solving cannot start unless the problem is sufficiently understood from all viewpoints. Then, it is difficult to search actively for a solution and the learning process does not proceed.

4.2.2.2 Find and Develop Solution

In 2011 the situation gradually started to change. More focus and attention were devoted to the problem, resulting in more problem solving activities and eventually the development of a solution. First, as part of a larger improvement project at Sunndal plant, the plant manager decided to direct focus to the anode quality issues. He called in to a meeting at Sunndal where a governance manager from PMS was involved and given responsibility to address these issues. He was involved because, as he puts it:

> It was a part of my role to be part of such meetings. So organizationally I was a natural part of those around the table in the discussion.
>
> Governance Manager, PMS

After being given the responsibility to address the anode quality he gathered people with knowledge of anode production into several improvement workshops. The participants at these workshops included technical personnel from PMT as well as operational personnel, both from the Sunndal plant and the Årdal plant. These workshops contributed to the learning process by connecting relevant knowledge that existed in the organization. Leading to several possible solutions being suggested.

During these workshops the first attempt to solve the problem emerged. The attempted solution was related to a specific machine used in anode production. The idea came as a result of the Årdal plant having this machine installed in one of its two anode production lines, with seemingly good results. Thus, a project was initiated to acquire a similar machine for the Sunndal plant. However, this attempt did not improve the anode performance. This attempt to solve the problem failed because they had not yet understood the root cause of the problem. Nevertheless, it seems that to a certain extent, also the failed project contributed to the learning process as it initiated a more active type of problem solving, and they learnt more about what the problem was not related to.

Several incidents lead the different stakeholders to believe that the problem had to be handled at a more fundamental level, and that it was necessary to look into the anode recipe. Thus, developing a new anode recipe gradually emerged as the most promising solution to the problem. First the governance manager got various inputs from his network, both through organized workshops and informal conversations with co-workers. Among others, a central input came from a senior PMT researcher. To the governance manager he argued that the future lied in a different recipe philosophy than the one being used by the two anode production lines within GFOS. Thus, a very important contribution to the learning process was simply finding, meeting and talking to people within the organization that may possess knowledge relevant for the problem. This was achieved both through active searching, and by more coincidental meetings.

In order to further develop this idea, the governance manager requested that PMT gave a newly rehired scientist the responsibility to get an overview of different anode recipes and the underlying technology, with the purpose of developing a new type of recipe for the Sunndal plant. As he puts it:

> What I did was that I asked PMT to put her on the project with the purpose to develop a new recipe philosophy. And understand our old recipe. We have had the old one for so long that very few people dared to challenge or ask questions about it.
>
> Governance Manager, PMS

Thus, resources from PMT was also involved directly at the Sunndal plant. The researcher that was put on the project eventually got the role of SPOC for the carbon business area at Sunndal. While this position did not formally exist in the early phase of the project, it is the position she held during our interviews, and for simplicity we will refer to her by this role throughout the whole analysis.

The SPOC then took on the task of acquiring and developing knowledge of anode technology. On her previous employment in PMT she worked with cathodes, which is a different part of the electrolysis, so she had little previous knowledge of anodes. Therefore, she read up on relevant theory; both published papers and internal technology reports. It seems that, by having higher education in a related field she was relatively easily able to gain considerable knowledge of anode production. In addition, she saw the need to learn the practical aspects of running anode production, and spent much time at the Sunndal plant, talking with the operational staff. This resulted in her gaining a good understanding of the anode production. As will be elaborated later, the SPOC played an instrumental role towards integrating and implementing the new recipe at the Sunndal plant. This process where she actively developed a body of understanding and a body of practice seems important, because this knowledge laid the fundament for the later development and modification of the technology.

However, it was not immediately clear for the SPOC why the Sunndal anodes cracked more frequently in the electrolysis than other anodes. Together with the staff at Sunndal she conducted many measurements of the anodes, but the results were not helpful.

> All the parameters we had defined as quality parameters on baked [finished] anodes showed that they had never been as good as this. And the anodes looked great, there was nothing you could see on these anodes.
>
> SPOC, PMT

Consequently, the SPOC was puzzled by the contradiction between their own measures and the performance results reported by the electrolysis. At this point they believed the problem was due to variation in production - that something in the production reduced the quality of certain anodes. Thus, the focus was on continuous improvement and stabilization of the production process, while the idea of changing the recipe was not actively developed further.

An important event that helped them better understand the problem and change the focus of problem solving happened when they decided to take a random sample of finished anodes, and split them open. When doing this they were surprised to find that every single one of the sampled anodes had internal cracks. It then became evident to anode production that the problems in the electrolysis was in fact caused by weaknesses inside the anodes. This discovery made it clear that the problem could not be solved by making incremental improvements to the process, and a more fundamental improvement was needed.

> We can't just try to avoid variation; we need to do something new. And that was kind of a eureka moment, that this was the case. An acknowledgement that; alright it's not the variation, it's the whole concept.
>
> SPOC, PMT

Thus, after realizing that there was a problem with the anodes at a fundamental level, the idea of developing a new anode recipe, seemed more attractive. It seems that because they have acquired more problem related knowledge, and because of that learned the real reason for the problem, the real solution also surfaced as the most promising.

The general theory behind the new type of anode recipe was well known at this point, at least to the SPOC and the governance manager. However, how to to go about actually implementing it in practice was much more unclear.

> We do have internal technology reports too, that have sort of said that this is the way to go, we should move in that direction. So it was very well known. (. . .) But we didn't really know how far in that direction, and how we should get there.

SPOC, PMT

Consequently, there was still no directed effort towards implementing a new recipe.

An important contribution towards getting them to actually try to develop a new recipe was a very specific request that came from the electrolysis. Due to a staff exchange within Hydro, the electrolysis got a new unit manager that had previously been unit manager in the electrolysis at one of Hydro's joint venture plants. He reported that there were no such problems there, and challenged the anode production unit at Sunndal to create anodes of similar quality.

> So what really kicked off that this is what we are going to try, it was that new electrolysis manager who came from [joint venture plant] and said; I want that kind of anodes.
>
> SPOC, PMT

It turned out that the particular plant he came from used the new type of anode recipe. Thus, they become more confident in that focusing on the recipe could actually solve the problems in the electrolysis. Moreover, the specific request gave them a clear target, and not just a direction.

However, while it now seemed clear how the problem could be solved in principle, not everyone was sure that the solution would be feasible in practice. This was because there were some doubts as to whether the old machinery in Sunndal was able to run the new recipe type. In contrast to Sunndal, the joint venture plant, that had successfully implemented this recipe type, was recently built and had all modern equipment.

> Several people told me: "You cannot run an old, classical, tore-down, overloaded plant, and then compare it with a new and modern one. You will not be able to pull that off". That is what some people told me, included some of the best researchers on this field within PMT.
>
> Governance Manager, PMS

While at a business trip, the governance manager was able to meet one of the engineers working with anode production at the joint venture plant. Interestingly, this engineer had previously modified an old anode production line, similar to the one at Sunndal, to run the new recipe. Thus, he could provide a strong case that it was actually feasible to use the new recipe in an old anode production line.

After getting approval from Hydro's counterpart in the joint venture, the governance manager organized a workshop in Oslo, where he flew in the engineer so he could meet and explain his experiences to the SPOC and the operational staff at Sunndal anode production. This workshop had two important beneficial effects. First, it provided both specific knowledge, as well as practical advices on how the recipe could be changed, and how the production line could be modified to produce it. Second, it gave the involved people a strong motivational boost and a can-do attitude.

> The engineer from the joint venture plant was very central in the sense that we knew our goal. (...) It was very important, because in that workshop was the area manager, and the unit manager, and I think also the technical manager, and they got to hear about his experiences from that old plant. And that was sort of; “Yes, then we should be able to do this too!”.
>
> SPOC, PMT

> We do know that process from before. We do know [the technical details of the new recipe type]. So we knew about the technology. But it was first when the engineer from the joint venture plant was there and explained what he had done on that old plant, which was actually pretty similar to ours. That was when we saw that: “Hey, here we have a real opportunity”. But that again was triggered by the fact that we had these problems in the electrolysis. That we weren’t able to figure out. So that process from that meeting, that was when it started, and a plan was laid out for how this should be implemented.
>
> Area Manager, Anode Production

Thus, a solution was found and the workshop turned into a kick-off for the anode recipe project.

4.2.2.3 Integrate Technology

The third and last part of technology introduction in the anode recipe project was the process of integrating the technology into the existing production system. This was done through a set of tests which, after positive results, lead to a permanent shift to the new recipe.

The tests were conducted directly in the operating production line. This was chosen instead of doing a pilot run in a lab. The advantage of doing the test directly in operations is that it is the most representative way of testing. In addition, as pointed out by the governance manager, doing tests in production involve the operating unit to a much larger extent.

> So, we decided that we would rather do a test in regular operations. Then you involve the organization in a completely different way, and it's not more difficult. It's actually quite easy to run a test in a factory if you just think about it. (...) The point is to actively manage the risk.
>
> Governance Manager, PMS

Compared to a lab test, it involved a greater risk, which had to be managed. First, the risk that the anodes produced during the test turned out useless. Second, the risk that it would be difficult to reverse the production system to the old recipe. The second risk was greatly reduced because the Sunndal plant (for historical reasons) had a parallel anode production line that was not used in daily operations. Thus, they could make the changes on the "spare" production line, and simply switch between the two during the test. This fact contributed significantly to reduce the risk associated with messing up the original production line.

> And when we ran the tests we used the spare production line. So, we have two separate production lines that can be used in the same process. And that was very nice, because then we could simply turn it on, and if something went wrong we could simply "click", one button, and then you're back to the other system. So we didn't have to worry about not being able to reverse the system.
>
> SPOC, PMT

However, it would still occupy production capacity during the test and consume the inputs. Thus, the risk of useless anodes had to be managed. This was done by conducting a two-stage test. First, a small set of anodes were produced with the new recipe, simply to verify that they were in fact able to create functioning anodes with the new recipe. After a successful first test, a second much larger test was conducted that was closely tracked in the electrolysis. A test of this scale was necessary to get statistically significant results when determining whether or not the new anodes were an improvement.

In this process it was critical to get all stakeholders on board, and in particular to get acceptance on the risk from decision makers. The unit manager at anode production was brought in early in the process and agreed to conducting the tests. Close collaboration with the electrolysis was also important. As end-user of the anodes they also had to bear the risk of potentially useless anodes. Thus, it was necessary to get acceptance to run the tests. Getting this acceptance was achieved through the two-stage testing. By starting with a small number of anodes in the initial test, the risk was kept to a minimum. Furthermore, the fact that the electrolysis had been troubled by poor anode performance from Sunndal over a long period of time made them willing to bear some risk for the chance of improvement.

While the technology to be integrated consisted primarily of a new recipe, it had implications for the production process. Thus, there was a process of adapting the existing machinery to the new recipe. This required the use of local competence together with PMT competence. A PMT researcher that had previous experience from adjusting the anode production line at the Årdal plant contributed. Together with a technical manager at Sunndal having more than 30 years of experience working with the anode production.

> The technical manager 2 made adjustments based on how he thought it should be; "We need more of this, and more of that". Based on his competence and experience.
>
> Technical Manager 1, Anode Production

Before making the adjustments, the SPOC had precalculated some required output values. Surprisingly, they reached the required output value at first try. While confident that they would reach the value eventually, making it on first try was admittedly due to some luck.

While successfully getting the machine to produce at the desired output levels, another problem occurred. Due to changes in production parameters the process was put out of balance. While not causing immediate problems, it leads to an overconsumption of certain inputs and underconsumption of others, which would eventually force the process to a stop. The first test lasted just short enough to avoid this problem, but it would make it impossible to run the new recipe on a permanent basis. This problem was solved primarily by the SPOC, and required her to do a theoretical modelling of the whole production process and perform calculations. According to one of the technical managers at Sunndal, her competence was important to solve this problem. She has more knowledge than us on mass balances and such, and runs the calculations.

> That's not part of my daily work, you know. We are just observing, call it more practically.
>
> Technical Manager 2, Anode Production

Interestingly, when talking about this particular problem, the researcher emphasizes that this was not a situation she would have thought of on her own. But rather emphasizes the importance of local competence about the production system to become aware of the problem.

> What I don't necessarily know all about is the types of extra challenges they get with respect to mass balances and those things. Because that is something they know more about themselves. While

> I am one of the few that actually try to find theories about why this works.
>
> SPOC, PMT

Thus, it seems that when solving this problem, the combination of the body of practice in operations and the body of understanding in PMT was necessary.

4.2.3 Influence of Structural Elements

In the anode recipe project, we have identified six structural elements which influenced the organizational learning processes and the ability to successfully introduce new technology:

1. Employee Transfer
2. Governance Function
3. Single Point of Contact Between R&D and Operations
4. Project Manager
5. Incentives for Cooperation Between R&D and Operations
6. Cooperation Between Operational Units

In the following sections each of the structural elements will be described, and their influence on organizational learning in the anode recipe case will be analyzed.

4.2.3.1 Employee Transfer

As a structural element, employee transfer can be intended as part of a larger plan for employee rotation, or simply a result of coincidences. In the anode recipe case we have seen that employee transfer had an important influence on the learning process, and specifically on the process of finding and developing a solution. In particular two incidents of employee transfer will be highlighted here. First, the transfer of the new unit manager in the electrolysis. Second, the governance manager's previous employment as a technical manager at anode production at Sunndal.

First, as was highlighted earlier, in midst of the improvement project at Sunndal the electrolysis got a new unit manager. He had been transferred from a similar job at a joint venture plant where they did not have the anode crack problems. Due to his previous position he had knowledge of a place in the organization where anode production was very successful. By sharing this knowledge with anode production at Sunndal he gave them a lead on a possible solution. After looking into this they realized that the joint venture plant was running the new type of anode recipe. Thus, the fact that he challenged anode production at Sunndal to create the same quality anodes as they did in the joint venture plant was an important contributor to changing focus towards anode recipe as the solution.

Second, due to a previous employment as technical manager at Sunndal, the governance manager had experience from anode production. This gave him both network and a first-hand knowledge of anode production and its underlying technology. The fact that he had this knowledge and network was important for the role he played in finding and developing the solution in the project. By having in-depth knowledge about the technicalities of anode production, he was well positioned to understand which development efforts to focus on, and to see the whole picture. By having a good network within the business area he governed, it was easier for him to find and meet the people with the relevant knowledge. Thus, previous employment in the area he governed seemed to have positively influenced his ability to help with finding and developing a solution.

Thus, this case showed that employee transfer lead to an exchange of knowledge between parts of the organization that would otherwise not have happened. Specifically, the process of finding and developing the solution was positively influenced by a broader access to knowledge of the problem and potential solutions.

4.2.3.2 Governance Function

This project was organized according to the company's three-party cooperation, and therefore involved a governance manager from PMS. The governance manager's role was to coordinate and allocate resources to improvement projects within his business area of focus. At the time this project took place, there were four governance managers working in PMS, each focusing on a specific technical business area within Primary Metal. The governance manager responsible for this project was responsible for the Carbon (anode production) business area in GFOS. Because he was situated in a separate organizational unit, and had some influence over the decision processes in PMT and anode production, he functioned as an integrating manager. Most of his influence came from the fact that he was in charge of allocating a considerable amount of money to initiate technology improvement projects. The funds controlled by the governance manager came from the operational units, and he was given the authority to coordinate and allocate these funds to improvement projects that were considered most beneficial to all of the units within the business area.

The governance manager played an important role in the initiation of the project. More precisely, he contributed to finding and allocating the resources needed to understand the problem and finding a solution. In the following analysis the governance manager's role in this project will be split into two: governing the financial resources and connecting the human resources.

First, improving and developing new technology required financial resources. Because it was the governance manager who was in control of the budgets for improvement projects for the business area, it was ultimately up to him to prioritize where and when different technology development projects took place. As an integrating manager the governance manager was well positioned to do an objective prioritization across all the plants. Because he was situated in a separate unit he was not part of any internal competition over financial resources between the operating units, but rather in a position where he could be equally concerned about all units and maintain an overview of their needs. The need for someone like the governance manager to allocate the financial resources was supported by the technical manager in the electrolysis.

> There is a purpose in having someone who are able to prioritize resources across the plants. Because everyone wants funding, that is just how it is. And if you don't have someone who has the overall control and responsibility of delegating the available resources, the one who screams the loudest will get the most.
>
> Technical Manager 3, Electrolysis

Furthermore, as discussed in the previous section, the governance manager had previously worked as a technical manager in anode production and therefore had in-depth technical knowledge of the process. This enabled him to prioritize based on technical considerations.

Second, technology introduction also depended on human resources with specific knowledge. As showed earlier, it was important that various forms of knowledge were combined in order to successfully integrate the new anode recipe in operations. Because his role was to govern technology projects within Carbon, he had a good overview of the knowledge that existed on anode production within the organization, and where it was located. Therefore, he was in a good position to find people with specific knowledge on anode production. In addition to knowing where in the organization the knowledge resided, he held a position that gave him authority to call people into meetings and workshops. As he expressed it himself:

> I was in a governance role in the carbon business area. I had the ability to call into meetings, and people would show up. Because I had a role that involved management over the carbon area.
>
> Governance Manager, PMS

By arranging workshops and meetings the relevant people were connected. This resulted in a combination of the body of understanding held within PMT and the body of practice of the operating units.

4.2.3.3 Single Point of Contact Between R&D and Operations

As previously described, new technology is often developed in PMT before it is transferred to and integrated in operations. The cooperation and communication between PMT and operations is formalized through the SPOC function. The SPOC was employed and situated in PMT, and served as a contact point between anode production at Sunndal and the carbon research area in PMT. Thus, as a structural element, the SPOC served as a liaison position in this case.

As showed earlier the form of organizational learning that occurred in this case required a body of understanding of anode technology. This resided in the PMT, and therefore the technology development took place in this unit. The transfer of the technology from PMT to operations was managed by the SPOC. Moreover, during the implementation of the technology several adjustments had to be made, and solutions to problems had to be developed. Some of which required a deeper theoretical understanding of the problem than what resided in operations. Therefore, the SPOC was not only needed to transfer the technology into operations, but also to do modifications during integration of the technology. Thus, from this case it seems apparent that during introduction of new technology, central pieces of the organizational learning is handled by the SPOC.

In the following we will go through the findings that indicate how the SPOC as a structural element influenced the learning processes in detail. By this, we will show that successful introduction of new technology required an interface between the R&D unit and operations in the form of a contact point that exhibited the following characteristics: a) possessed the relevant body of understanding, b) understood the existing production system by accessing the body of practice in operations, and c) was able to interact broadly with operations.

First, solving the problem with cracks in the anodes required a more theoretical understanding of anode production than what resided within operations. Thus, in order for the problem to be resolved, Sunndal needed someone with a deeper body of understanding on anode technology. Part of the solution to this problem was related to understanding the whole process of anode production, and more specifically understanding how changing the anode recipe would affect the whole process. This could not be done effectively by a trial-and-error approach by operations, but rather required a conceptual understanding of the anode production process. Thus, finding a solution to this problem depended on the SPOC, and the knowledge in PMT she represented.

As the one of the technical managers mentioned, his focus was not on the theory and computing mass balances. His focus was on the more practical aspects, making sure that the process ran smoothly. He mentioned that one of the greatest contributions to the project was the knowledge the SPOC possessed.

> The knowledge she has was important; you should not forget that.
>
> Technical Manager 2, Anode Production

Thus, having someone with a body of understanding on anode technology was a premise for solving the issue with anode cracks and the organizational learning.

After developing the solution, the SPOC was responsible for transferring the new technology and knowledge to operations at Sunndal. In addition to transferring the technology, the SPOC was responsible for integrating the new technology with the existing production line. Thus, it was not sufficient for the SPOC to have the knowledge that enabled her to develop a new technology. The SPOC also had to understand the existing technology to be able to integrate the technology.

Second, when bringing new technology into existing operations, knowledge about the existing technology was critical. In particular, it was necessary to handle the problems that occurred due to imbalance in the process. This required a combination of both body of understanding and body of practice. According to the SPOC herself, she did not have any previous experience with anode production. Therefore, she relied on accessing the body of practice possessed by operators and technical managers at Sunndal by being present in operations.

> Because I did not know anything about anode production, I learnt that during the tests we conducted in operations. Because then I was there, and they [the operators and technical managers] taught it to me. They do not understand that it was they who did it.
>
> SPOC, PMT

Getting this practical understanding of operations and the technology required the SPOC to interact with, and be present in, operations.

Third, in this case it was observed that part of what made the integration of the new technology successful was the broad interaction the SPOC had with the operating unit at Sunndal. As highlighted by the SPOC, it was important to involve operations in all parts of the process. As an external person bringing new technology into the operating unit, being present and talking to a broad range of operators was necessary.

> Well, you only get ownership by the operators if you, in a way, if you also get dirt on your hands.
>
> SPOC, PMT

Successful integration of new technology required that everyone affected was involved in the process. This allowed the involved parties to learn about the new technology, and at the same time give feedback to the SPOC on how adjustments to the new technology could be made in order to fit the existing production system. The importance of involvement and broad interaction from the SPOC was also confirmed by one of the operators involved in the project.

> Very satisfied with the personal involvement [from the SPOC] in this project. And I absolutely think that it is one of the success criteria here. Because, if you get a directive, or just a message that this is how it should be done, from a more distant person, you won't get the same involvement from us in operations either.
>
> Operator 1, Anode Production

4.2.3.4 Project Manager

We have showed that part of the learning in this case occurred as the technology was tested and implemented into operations. An important influence on the success of this process is the project manager function carried out by the SPOC. As stated by informants earlier, her competence and knowledge was important, but equally important were characteristics that seem related to project management. In particular, two sides of this function have been brought up as particularly important for the success of this project. First, her involvement and commitment to the process, through frequent follow up, and simply being present at the production site during tests. And second, her having the overall responsibility for the project.

> The SPOC has been out on evening shifts, and been in touch with the night-shifts. That's a key for these types of projects in the implementation and testing phase to be a success. You need to have someone to be the red line through the whole project.
>
> Area Manager, Anode Production

Furthermore, it is interesting to note that instead of emphasizing her knowledge of anode production technology, she highlighted her experience with managing tests in an operating environment as what she was best at.

> The thing is that, I had only worked one year [with anodes]. I didn't actually have that much competence in anode production. What I did have a lot of competence in was to run tests in an operating environment. (...) From experience I know that nothing happens unless you are present, you can't just send an email to operators, that doesn't work. So you need to be present.

SPOC, PMT

This was also confirmed by the operating staff, highlighting the importance of involvement by those conducting the tests. Both as a contributor to general motivation and learning, and to make sure that the project was actually carried out as intended.

> She spent much time here. Of course we were skeptical, like more or less all shift-employees are, when there's someone new coming in, and is supposed to tell you "no, you should not do that, listen, here's a new idea". Then there's a little skepticism, always. Because we would rather do it the way we are used to do it. But she is very good, energetic and ongoing, and got us to participate in the tests. Involved us in the tests, explained, very important, explained what she expected, and what was going to happen.

Operator 1, Anode Production

Thus, when integrating new technology into operations, simply installing the artefacts and sending emails with new instructions will not suffice. The process is far more complex, and there is a need to exchange knowledge between researchers and operations. Therefore, a more media rich channel is necessary, and as shown in this case, being present and talking with operators was important.

Moreover, being present seemed to be important in order to handle unexpected events, and be able to make adjustments to the plan on the fly.

> And it's about being present, and if it's like this, and you want it to be like that. Then you need to know that it's not sure that it's going to go like that. So then you need to be present and register that: "okay, it didn't go that way, then we need to readjust".

SPOC, PMT

In addition to her abilities as a project manager another factor seemed highly relevant for the success of this project. Simply the fact that she was external to operations and in that sense freed from the time pressure on operational units.

> You need to have time during work to sit down and plan this. I spent quite a lot of time calculating the different percentages we needed out there. And that's the point of coming from a technology organization; I could sort of free up a day, just to gather data from the system and process it. (...) And then I have time to make a list that says in three weeks I'll make sure to follow up this, and

> then I can set aside three hours to do that follow up, right. I have a completely different flexibility when planning my day. In terms of being able to work concentrated with one thing over a longer period of time.
>
> SPOC, PMT

The importance of her ability to plan and manage her own time, as wells as the lack of it in the operational unit was also clearly confirmed by other informants.

> The SPOC had the ability to support operations; run analyses, conduct tests, take samples. In other words, work in a completely different way than one have time to do in daily operations.
>
> Technical Manager 3, Electrolysis

However, it may not simply be a matter of having time, but just as much a matter of being able to have a different focus and perspective on things, and simply pushing the operational unit to go through with the project, as suggested by the unit manager at Sunndal:

> The SPOC pushed us to do things we otherwise wouldn't have made the time to do. When you're having a lot of problems in operations, you always have time, but it's a matter of prioritizing. But she helped us focus, and was out in the production facility, taking samples and it made others realize that, damn we can do that too.
>
> Unit Manager, Anode Production

In conclusion, being freed from operational pressure and her ability to manage her own time was important for being able to manage the integration project. The implication of this is that technology introduction should be organized as a project operating parallel to daily operations, and managed by someone that is not responsible for daily operations.

4.2.3.5 Incentives for Cooperation Between R&D and Operations

This case showed that the incentives given by the organization for the R&D unit to cooperate with operations influenced the processes of understanding the problem, finding and developing a solution, as well as the process of integrating the new technology into operations.

From the viewpoint of anode production at Sunndal, their cooperation with PMT became significantly better a few years before the anode recipe project was initiated. The reason for this change was a structural change in the funding of PMT. Before the reorganization, PMT received a pot of money from Hydro, and managed the funds as they wanted. As a result of this structure, anode production at Sunndal, felt that the Årdal plant, where the majority of the research on anodes take place, received a lot more support. Due to differences in the production lines at the different plants, technology developed for anode production at Årdal did not necessarily fit the anode production at Sunndal. This is how the area manager at anode production at Sunndal experienced the "old" PMT organization:

> Previously, PMT was a very closed organization. They got a bunch of money, and was allowed to do whatever they wanted with them. They managed the pot of money themselves, there was nobody who was interested in what we wanted.
>
> Area Manager, Anode Production

Then there was a shift in the structure of how PMT received funding. A portion of the funding would still come from Hydro centrally, but PMT now had to collect the other portion from the operating units. Sunndal then experienced a shift of focus from PMT. According to the same area manager it was necessary for PMT to be challenged, and forced out of their comfort zone, in order for them to shift their focus to Sunndal and the other plants as well.

> Suddenly, PMT was challenged [by Hydro] to go out and collect some of the funding from the different plants. And then they had to start selling their services; "You see, we are here, we have a lot of knowledge, what can we do for you?". I think that was the reason that PMT had to start working in a slightly different way. (...) When they had to start collecting their money from us, that is when the shift of focus started to happen.
>
> Area Manager, Anode Production

This indicates that making PMT more dependent on operations for funding, created an incentive for them to more actively approach and help Sunndal with their problems. This active cooperation contributed to the identification of the real cause of the anode problems, and the development and integration of a new anode recipe. Primarily because PMT assigned the SPOC to work with anode production at Sunndal.

4.2.3.6 Cooperation Between Operational Units

The cooperation between the anode production and the electrolysis influenced technology introduction. In particular, it influenced the process related to

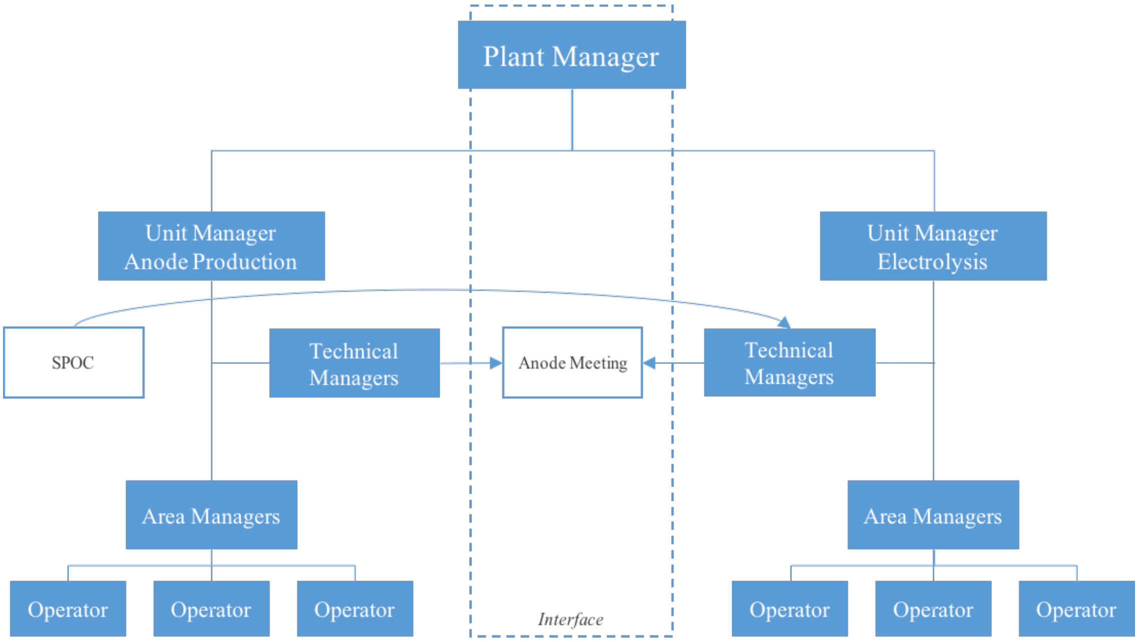

Figure 4.7: Overview of Relevant Units at Sunndal Plant, Indicating the Interface Between Anode Production and Electrolysis

identifying the problem and running tests in operations. The cooperation between the two units was managed through the interface defined by the hierarchy. Before proceeding with the analysis, the structure of the two involved units at Sunndal plant, and the interface between them, is outlined in figure 4.7.

This case showed that having a hierarchical structure at the plant encouraged vertical coordination, but hampered the horizontal coordination. The hierarchical management incentivized each of the two units to focus on their own predefined target measures, as this was the performance the unit managers were held accountable for. As a result anode production worked towards improving their performance on these predefined measures. However, as this case showed, the quality parameters measured by anode production did not relate well to the actual performance of the anodes in the electrolysis. As several informants highlighted, their own measures told them that their anodes had never been better. Thus, they had no reason to change their anodes. The only real incentive for anode production to actively change their anodes according to the performance in the electrolysis would be if their own performance measures were better related to the anodes' performance in the electrolysis.

This shows that a hierarchical structure gave strong incentives to reach the targets set for the unit. The danger however, is that if the target measures do not relate well to the performance of neighboring units, measurement system may come at the cost of horizontal cooperation.

Furthermore, there are two structural elements that determined the horizontal coordination between anode production and electrolysis during the anode recipe project: anode meetings and the SPOC.

The anode meetings were held weekly, and involved technical managers from both units. During these meetings topics related to anode quality were discussed. However, these meetings only served as a way to communicate the problems to each other, and did not contribute to finding and implementing a solution. A possible explanation for why these meetings had little actual impact could be a combination of two things. First, none of the participants at the anode meetings had any formal authority over the other unit. In fact, the first person in the hierarchy that has authority over both units was the plant manager himself, and these meetings were too far down in the organization for him to be involved. Second, as shown above, both units were primarily incentivized to focus on their own performance measures.

The SPOC is another structural element that influenced the cooperation between the two units. As figure 4.7 shows, the SPOC was situated outside of both anode production and electrolysis, and was therefore not subject to the vertical authority in the same way as the operating units. The SPOC was involved in this project through PMS, which again was involved through the task force set down by the plant manager. As was highlighted earlier, the plant manager was interested in the joint performance of the two plants, and since the SPOC indirectly represented the plant manager in this project, her focus was also on joint performance. It was especially during the integration of the new technology that the SPOC worked closely with the electrolysis. This was necessary in order to get acceptance from the electrolysis to run the tests and to define the necessary success criteria for accepting a permanent switch to the new recipe.

4.2.4 Summary of Within-Case Analysis: Anode Recipe Project

Throughout this case analysis we have seen several ways in which the organizational structure has influenced organizational learning. In the anode recipe case organizational learning was driven mainly by three processes; identifying the problem, finding and developing a solution and integrating the technology. Each of these processes were influenced by different structural elements. An overview of how the different structural elements influenced the learning processes is given in table 4.1.

Table 4.1: Structural Influences in Anode Recipe Project

Structural Element	**Identify Problem**	**Find and Develop Solution**	**Integrate Technology**
Employee Transfer		New unit manager in electrolysis had previously worked at a plant without anode crack issues. This provided a lead for a possible solution. Due to previous employments, the governance manager had a broad network and in-depth knowledge of anode production. This enabled him to know who to involve in the project.	
Governance Function	Identified and connected relevant technical knowledge with operations at Sunndal, which helped to understand the problem.	Identified and brought in relevant knowledge to the project, including engineer from joint venture plant. Allocated financial resources to develop new anode recipe.	
SPOC	Assisted anode production with relevant knowledge and systematic methods for problem identification.	Acquired and synthesized available knowledge on anode recipes, and developed a new recipe, specifically for Sunndal.	Facilitated combination of body of practice and body of understanding. This was necessary to assess the impact of new recipe on the existing production system. This, in turn, was necessary to solve mass balance problems.
Project Manager			Having the technology introduction project managed by someone without operational pressure was important to see it through.
Incentives for R&D and Operations	PMT being dependent on operational funding made it necessary for them to take equal interest in the problems of all operating units.	PMT being dependent on operational funding made it necessary to develop technology for plants.	PMT being dependent on operational funding made it necessary to support operations with integration of the developed technology. This was facilitated through the SPOC.
Cooperation Between Operational Units	Through anode meetings, the electrolysis could raise their concerns regarding anode quality. Performance metrics incentivized the two units to focus on their own targets. Problematic because the metrics in anode production did not relate well to performance of anodes in electrolysis.		Acceptance from electrolysis was necessary to test and implement new recipe.

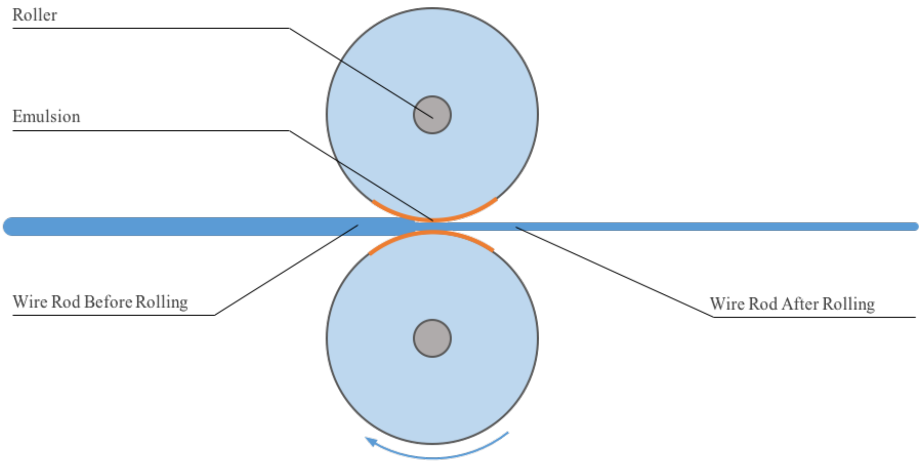

FIGURE 4.8: Rolling of Aluminum Wire Rod

4.3 Within-Case Analysis: Emulsion Project

4.3.1 Introduction to the Case

This case is centered around the Wire Rod Casthouse at the Karmøy plant. Aluminum wire rod is one of several end products of Hydro's aluminium production. The aluminum wire rod serves as raw material for high voltage cable and wire producers. However, wire rod production constitutes a very small portion of Hydro's output, and the wire rod casthouse at Karmøy is the only producer of wire rod within Hydro. Organizationally, it is a part of Primary Metal, together with the other casthouses. At Karmøy it is organized as a separate unit and situated in its own building, separate from the main casthouse.

Unlike other forms of aluminum casting, wire rod casting includes a rolling process in immediate connection to the casting furnace. The wire rod production process consists of the following steps: melting aluminium, casting aluminium wire, rolling the aluminium wire and lastly coiling the aluminium wire. In the wire rod casthouse there are three melting furnaces, and two casting furnaces. After the casting furnaces the aluminium wire is lead into a series of rolling mills where it is rolled down to its final diameter, between 9,5 and 25 millimeters. Figure 4.8 illustrates how a roller works.

The *emulsion* is a critical component in the rolling process, and referred to as the heart of the production by the unit manager at the wire rod casthouse. It has three main functions; lubricating, cooling and cleaning the rollers.

The emulsion project was a project that introduced a new type of emulsion technology to the wire rod casthouse at Karmøy. The details of the new technology cannot be disclosed, and will therefore be referred to as the "new emulsion". The project was initiated in 2012 as a response to several problems

Figure 4.9: Timeline for the Emulsion Project

in the wire rod casthouse, of which variation in product quality and HSE issues related to disposal of the old emulsion were central. The new emulsion was acquired from a research unit within the Rolled Products division of Hydro, i.e. outside of Primary Metal. Within this research unit, one of the specialists on lubrication technology had conducted a research project from 2007 to 2010, that resulted in the development of a new emulsion. With some modifications, this technology was introduced to the wire rod casthouse at Karmøy. See figure 4.9 for an overview of central events before and during the project.

The new emulsion lead to immediate improvement of performance, reduction of costs and removal of the HSE issues. However, several new issues occurred that had to be fixed. Thus, after implementation, further modifications of the technology, as well as the existing production system were made by the local staff at Karmøy. Eventually, most problems were solved and the overall result was a significant improvement in the wire rod casthouse. It was recognized internally in Hydro as a very successful project and was awarded the Technology Development Innovation Award with the following explanation:

> Primary Metal's "New emulsion system for the Karmøy Wire Rod Casthouse" for excellent teamwork where competence from Rolled Products R&D is utilized in Primary Metal to optimize the emulsion of the wire rod production, improving quality, cost and work environment.

The project involved two organizational units within Hydro; Karmøy plant within Primary Metal and an R&D unit within Rolled Products. Thus, this project span across two divisions in Hydro. Figure 4.10 shows the relevant units, and the relation between them.

4.3.2 Organizational Learning During Introduction of New Technology

In this section, the empirical data from the emulsion project will be presented as a narrative of the events that took place during introduction of new technology. The emphasis will be on the processes that contributed to organizational learning: developing technology, identifying the problem, finding a solution and integrating new technology with existing machinery.

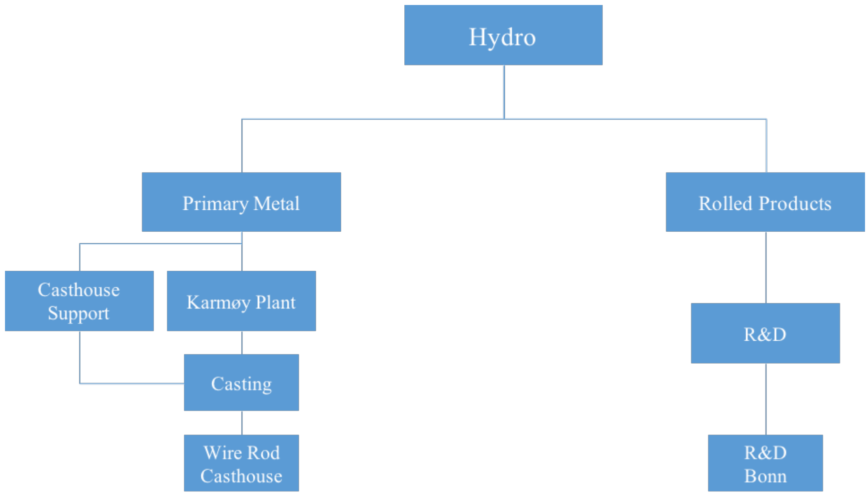

FIGURE 4.10: Overview of Organizational Units Relevant in Emulsion Project

4.3.2.1 Develop Technology

Each of Hydro's divisions have separate technology units, which performs research and development of new technologies. Technologies are developed either to solve a specific problem in an operating unit, or through applied research. The new emulsion technology that was implemented in the wire rod casthouse was originally developed by a senior research employed in the R&D unit in Bonn, which was part of Rolled Products.

The idea to the new emulsion was a result of the researcher having 35 years of experience with lubrication, as well as participating in a European project for lubrication chemists in the aluminium and steel industry. Through his contacts in the European project he became aware of a rolling mill in another aluminium company that was experimenting with a different kind of emulsion. Without any experience or knowledge about this particular technology the researcher began experimenting with the idea.

> Then I got the idea and developed, I selected ingredients for a new emulsion. It was not easy because we had no experience with it, and I was not really sure what they were doing in that other company.
>
> Senior Researcher, R&D Bonn

Over a period of three years, where the senior research received funding to conduct applied research, he developed the new emulsion. In R&D Bonn, projects were funded either by the management of the R&D unit, or by the customers, which was the plants in Rolled Products. This particular technology was not directly requested by any of the rolling mill units in Rolled Products, but his research was funded by the R&D unit. Thus, this was an example of how central funding enabled applied research that resulted in development of new technology.

4.3.2.2 Identify Problem

Over a longer period of time the wire rod casthouse at Karmøy were troubled by several issues with its production. They had an unstable process with significant variance across many production parameters. Expensive production stops occurred too often. Specific issues such as coiling of wire reduced the quality of the end product. In addition they had a major HSE concern related to cleaning the machines and dispose of old emulsion, a spill product of the process.

In the fall 2011 the wire rod casthouse got a new unit manager who came from another unit at the Karmøy plant. From his point of view, a challenge in the wire rod casthouse was a lack of overall perspective on the process.

> What I saw is that the way we are working at the wire rod casthouse is that we have very close monitoring of performance metrics, of drivers, of everything. Nobody is doing it in a structured manner, everything is fragmented in small, everything is divided into details. So, there is nobody that has a perspective on how things are related, right. So there is a bunch of performance metrics and drivers to follow up separately, because we have broken everything down, so you kind of forget the overall perspective on how it all is related.
>
> Unit manager, Wire Rod Casthouse

The consequence of lacking an overall perspective was that they were never really able to identify the underlying cause of the problem. Instead everyone was more focused on solving the particular problem they had that particular day, and problem solving was short term oriented.

> When you work in production the days go by the same, right. You get to work and check your performance metrics, right. You log in and see how it's going; how many problems did I have the last days, the last weeks, what's the problem today? Okay, so I had three incidents of this problem or seven of that. Now we need to do something about it, and then we work on that particular problem right; short term thinking.
>
> Unit manager, Wire Rod Casthouse

Despite the problem immediately at hand being solved, new problems would soon occur elsewhere in the process, and old problems would come back.

Effectively, they were simply adjusting parameters according to the variation in the process. Thus, the consequence of this relatively narrow focus to problem solving was that the situation overall did not improve.

> What I see is that when we look at all the problems we have, we are able to fix them for a short period, and then they come back right. We haven't really solved the root cause of the problems. We have all the same problems, and depending on variation in where the problem currently is we change focus.
>
> Unit manager, Wire Rod Casthouse

After becoming aware that this is the situation, the unit manager decided to attempt a more holistic approach to identifying the problem. He did this by calling into meetings with various personnel at the casthouse, and used a set of analytical frameworks to get an overview of all the problems, and tried to see the connection between them. Through this process they were able to identify that the emulsion seemed to be related to many of their problems.

> What we realized fairly quickly was that we had a three-month cycle where we dumped the emulsion [removed it, cleaned the tanks and added new emulsion], and when we did that everything would work again. But then we had to adjust the production back in, right, with new quality. And from day one it became worse, so we made adjustments all the way, until it became so bad that we had to dump the emulsion again.
>
> Unit manager, Wire Rod Casthouse

From these analyses they concluded that the root cause to many of their problems had to be related to the quality of the emulsion. As will be clear from the next steps, the decision to focus on the emulsion eventually lead to an effective and sustainable solution to the problems.

4.3.2.3 Find Solution

Having learnt that the problems were caused by the emulsion, operations at Karmøy faced two alternatives for solving the problem. Either they could try to modify the emulsion themselves, or they could look to other business areas within Hydro for ideas.

The operations at Karmøy quickly realized that they did not have the relevant expertise to solve this problem themselves, and therefore needed technical assistance. However, because the problems were caused by the emulsion, the local R&D unit supporting the wire rod casthouse - Casthouse Support - was not able to assist. Emulsion and rolling is not normally a part of the casthouse and consequently, Casthouse Support did not have any competence in that area. Being the only wire rod casthouse in Hydro, Karmøy is the only casthouse that uses rolling technology in their production process.

> The competence [about emulsion] in the wire rod casthouse, and at the Karmøy plant in general, was insufficient.
>
> Operator 3, Wire Rod Casthouse

From a learning perspective, the fact that the competence on emulsion did not exist in operations at Karmøy nor in their immediate support network was problematic. Without access to required knowledge, the learning process would have stopped, almost immediately after it had started. Therefore, to continue the learning process Karmøy had to look outside the Primary Metal division for assistance.

There were two initiatives to find competence on emulsion technology within Hydro. First by the procurement manager in the administration at Karmøy, and second by the unit manager in the wire rod casthouse. The procurement manager was interested in finding an alternative to the old emulsion because of the high costs related to it.

> The clue was that we in procurement worked on cutting the costs through Hydro's cost-saving-program, and we aimed to lower the production costs. (...) As the responsible procurement manager for the casthouses, I saw that we had a huge cost related to removal and deposit of the emulsion. So, my interest in finding a solution was that I saw that we spent a lot of money on this, and that we wasted a lot of aluminium.
>
> Procurement Manager, Karmøy Administration

Through a casual meeting with the HSE manager in the Karmøy administration, the procurement manager understood that also he was interested in finding an alternative to the emulsion because of the HSE issues related to cleaning and emptying the emulsion tank. Together they began to look into different solutions to the problem, and concluded that the wire rod casthouse resembled a rolling mill. Thus, they approached the purchasing manager for the rolling mill at Karmøy and asked him for help. This lead to several mail correspondences with various units in Rolled Products. Eventually, their emails were forwarded to the senior researcher in R&D Bonn in the summer of 2011. The senior researcher told the purchasing manager about the technology he had developed, and that he was interested in testing it in operations.

Then, over a period of several months information was exchanged over email. The senior researcher in Bonn requested information of the wire rod casthouse and became confident that his technology and knowledge could be helpful. However, at this point, those who were involved at Karmøy were a little hesitant, because of the costs involved and because they were not sure if this new type of emulsion was the way to go.

In late 2011 it was decided by the new unit manager at the wire rod casthouse to invite the researchers from Bonn to explore this possible solution. Through the problem identification process described in the previous section it had become evident that most of their problems were related to their current emulsion. Furthermore, the new unit manager had previously worked in a rolling mill unit in Rolled Products and therefore he had both experience and knowledge about rolling mills. As a result of his experience and knowledge he saw that there were a lot of similarities between the wire rod production line and the production line of a rolling mill. Therefore, he already knew that R&D Bonn was where the expertise on lubrication resided within Hydro and was confident that they could be of help.

> The challenge was the technical solution. I had previously worked with rolling mills, so I saw that this [the wire rod mill] in principle was a rolling mill. Here we have to contact the research and development unit in Rolled Products to involve the right expertise. Because there was nobody in our environment who had any knowledge about this.
>
> Unit manager, Wire Rod Casthouse

After the unit manager launched the idea about reaching out for help from the the R&D unit in Bonn, the purchasing manager let him know about his initial contact with the senior researcher in Bonn. The unit manager therefore followed up on this initial contact to invite the senior researcher and two of his colleagues to Karmøy for an initial workshop in the beginning of 2012. In this workshop he also included various operative personnel from the wire rod casthouse at Karmøy. The goal of the workshop was to bring together different sources of knowledge, to understand if and how the new emulsion technology could be used at Karmøy. The effect of this was that the body of understanding represented by the researchers from R&D Bonn was combined with the body of practice existing in operations at Karmøy.

> You have to make use of the competence that is available in the Hydro system. So the idea was to get input from others working with emulsion and rolling, not think that we should solve everything ourselves. (...) The point with the workshop was that we brought in much different competencies on different areas, to brainstorm around a challenge that we didn't have a technical solution to.
>
> Unit manager, Wire Rod Casthouse

During this workshop the researchers from R&D Bonn presented their solution, and it became apparent to the unit manager that the senior researcher in Bonn had developed a technology that could potentially solve the emulsion-related problems at Karmøy. They decided to proceed with this technology, and a project to integrate it into the Karmøy plant was established. The project group consisted of a project manager from Karmøy, two researchers from R&D Bonn and a technical manager from Karmøy. The project manager was a researcher from Casthouse Support, who worked as a quality manager for the wire rod casthouse. Thus, the focus shifted from searching for solutions to implementing the one they had found.

4.3.2.4 Integrate Technology

By identifying the root cause of the problems, finding technical competence and a potential solution, important knowledge was acquired. However, this alone did not solve the problems. The last and by far the most critical part of the process was the integration of the new technology into the existing operating environment. In this section the process of technology integration is reviewed in three phases; before implementation, during implementation and after implementation.

Before Implementation
As mentioned, a promising new emulsion developed by a researcher in R&D Bonn was found. Through the initial workshop at Karmøy, the researchers from Bonn learnt about the specific characteristics of the wire rod production line, and understood how their technology had to be further developed in order to fit the production system at Karmøy. After the workshop, the researchers went back to the laboratory in Bonn to make adjustments on the technology and to carry out pilot trials.

> After we validated “Okay, this is a technology we are going to put in our trials, in our casthouse”, then the researchers from R&D Bonn did more fundamental research, you know, and then they did pilot trials. And then we finally tested it in our production line.
>
> Project Manager, Wire Rod Casthouse

Through this process of preparation before the implementation, they were effectively learning before doing. By conducting tests in the laboratory, and in pilot facilities, they were trying to figure out beforehand if, and how the technology would work in practice. It is important to note that the new emulsion had originally been developed for a different type of rollers, and therefore it was necessary to conduct tests specifically for the wire rod casthouse at Karmøy. The result of this process was refinement of the new emulsion technology, and increased confidence that it would work in production.

> After this pilot trials, then I was sure, I said it would work for production.
>
> Senior Researcher, R&D Bonn

Management of risk beforehand was given much attention in this project. In addition to the testing and development conducted by the senior researcher in Bonn and his team, the staff at Karmøy worked hard to identify and reduce the risks associated with the project. The wire rod casthouse was the one who paid for the project, as well as the one who would have to bear the costs of downtime if the new emulsion did not work. Thus, it was important for them to minimize the risk of anything going wrong during integration.

> One thing was theory, another to do it in practice. The consequences are enormous. We have one line [for production of wire rod] in Hydro, and that is this one. If this goes poorly, I can't deliver to the customers. We can't do pure gambling, right, so I had to know that we could do it. So what I did was to sit down, and take an operational perspective on this. Analyze the risks, and map up everything that could affect this project, and set actions to solve those things we were unsure about. So we took a structured approach, to go through all the elements. Spent quite a lot of time on that.
>
> Unit Manager, Wire Rod Casthouse

Eventually they decided that they were ready to test the technology in practice, and the unit manager gave a go-signal for testing it in the production line. Having done extensive risk management beforehand was surely important towards making the decision of testing the new emulsion.

During Implementation
During the implementation phase the senior researcher from Bonn and his team returned to Karmøy. They were present for two to three weeks and assisted the staff at Karmøy when the old emulsion was removed, and the new emulsion was mixed and refilled to the system.

Immediately, the new emulsion seemed to be a success. It was easy to set up, and provided visibly improved product quality from the start.

> This experiment was started early in 2013. And it was extremely successful. I think we got it running within five minutes. And everything looked great, and it was all good. And the Germans, the research group, they went back. I don't know how long they were here, maybe 12 days, two-three weeks. It went very well.

Technical Manager 1, Wire Rod Casthouse

> Now the wire rod is perfectly straight. That was the visible result we got immediately. So we thought that this is great! We were very happy and gave ourselves a pat on the back. We felt that we had fixed this process, right.
>
> Unit Manager, Wire Rod Casthouse

Thus, everyone involved thought of the project as a success. The new emulsion had performed very well during its first days in production. The old problems were gone and product quality was improved. Naturally, it was decided to keep using the new emulsion. The researchers from R&D Bonn went back, and the operations at Karmøy were left with the recipe for the new emulsion.

After Implementation
However, the image of flawless success was soon shattered. A few months after the implementation, new, and unforeseen problems started to surface. They had various technical issues related to corrosion and tear on the machines. It soon became apparent that with the new emulsion the rollers were wore down much faster than before.

> It all looked like a great success. And it was like that for about three-four months. And then we got extreme problems when we had gotten that far. We got huge wear on our rollers. It was so severe that the maintenance unit almost wasn't able to keep up with the tempo we needed to switch everything out. So it was a big crisis, and we almost didn't know how to get out of it.
>
> Technical Manager 1, Wire Rod Casthouse

> But then the problems began. There was too little lubrication, and we got extreme wear on the rollers. We wore them down at once. That gets very expensive.
>
> Unit Manager, Wire Rod Casthouse

These problems were different than the ones they've had before, and were unanticipated. Despite of the extensive preparations beforehand.

> Of course when implemented, we knew that we could face some, some issues that were in our minds. But after implementing the technology, there were some hidden issues which came that we never forecasted.

Project Manager, Casthouse Support

When these problems started to occur, the researchers behind the technology had returned to Bonn. Moreover, the staff at Karmøy felt that they did not have the necessary knowledge to solve the problems themselves. Thus, they experienced it as quite problematic that the researchers were no longer present at Karmøy.

> Because the problem in the project, you know when you have researchers. One thing is to map up and do all the formal work, right, get everything ready for production. But when it gets into production they are gone, and then production sits in it. When the problems surface, what do we do then? And that's it, that particular line is very difficult; when should the project organization pull out, and when should operations take over?
>
> Unit Manager, Wire Rod Casthouse

It is important to note that there was indeed an effort on both sides to maintain the cooperation after the researchers had returned to Bonn. In particular, when the problems started to occur. However, the fact that the researchers were not present at Karmøy, and they had to communicate over email and phone seemed to reduce the actual help gained from this.

> It became a little bit tricky that this was a project with people in Germany and here [Karmøy], and communication. The Germans were very supportive during the project, but they are far away. They aren't close, and they don't know the problems, right. So when introducing new technology, to do a step-change, it is easy to let go too early, before everything is stable. We are still not finished.
>
> Unit Manager, Wire Rod Casthouse

> They [researchers in Bonn] have gotten samples sent to them, every week I think, so they have had control, but they weren't present. It might be wrong of me to think like that. But I think that if I was part of owning this, then I would want to have someone on the team, yes, maybe one person following the project for an entire year. Not all of them, but one person that had the required knowledge to see and follow up.
>
> Technical Manager 2, Wire Rod Casthouse

It seems clear then, that from the viewpoint of the casthouse management at Karmøy, presence at the plant is necessary for R&D personnel to be able to provide sufficient support.

Thus, as a consequence of the lacking support from the technical unit, the operational staff had to solve the problems mostly by themselves.

> So what we did, was that we brought back the problem solving frameworks; what is the problem? We started mapping up what affected, set up actions, and small teams. We had mechanics and operators on each task. So we divided up the work and followed up weekly.
>
> Unit Manager, Wire Rod Casthouse

While they may have had a structured approach to it, this process was largely dominated by trial and error. They were testing different modifications to see whether it helped on the problems or not. In contrast to the process before implementation, they were now learning by doing.

> They [researchers] were like "Sorry, we don't have any tips", so then we just tried something. Yes, screw it, let's just [modify the emulsion] and see how it goes.
>
> Operator 1, Wire Rod Casthouse

In this learning process, body of practice and extensive experience with the machinery were critical. In particular, the technical managers who both had more than 30 years of experience at the wire rod casthouse were instrumental to fix the problems.

> So I think the main reason that it worked so well is that there is a lot of expertise up here. (...) We have worked with this over some years, and we know the effect of [different challenges in production].
>
> Operator 3, Wire Rod Casthouse

Eventually they were able to solve the new problems. This included adjustments to the emulsion recipe, as well as modifications of the machines, to better suit the new emulsion. The solutions were of a practical kind, reflecting that this was primarily done by the staff at the casthouse. Nevertheless, they proved effective.

Interestingly the modifications that the staff at Karmøy came up with have been sent back to the research center in Bonn, and the ideas are being further developed there. A possible interpretation of this is that part of the reason that the researchers were unable to help solve the problems that occurred was their lack of access to a body of practice about the production system at Karmøy. Not being present did indeed disconnect them from the operating environment and the problems there, but possibly more important, it made it harder for them to access the knowledge possessed by the staff at Karmøy.

4.3.3 Influence of Structural Elements

In the emulsion project we have identified four structural elements which influenced the organizational learning process and the ability to successfully integrate new technology:

1. Performance Metrics
2. Network
3. Interface Between R&D and Operations
4. Incentives for New Technology

In the following sections each of the structural elements will be described, and their influence on organizational learning in the emulsion case will be analyzed.

4.3.3.1 Performance Metrics

Measuring performance according to predefined metrics was a central part of work in the wire rod casthouse. All the way from corporate management, through plant and unit management, down to daily operations, goals were defined and broken down into sub goals. Goals were linked to measurable performance indicators. At the operational level this meant highly detailed performance metrics, specifying target values for different process parameters. Each operator was responsible for a set of metrics when he or she was on shift. Actual performance on these metrics was closely monitored and reported upwards in the system.

> Because of the organizational structure and the way we are goal-oriented in Hydro, we break down all our goals into performance metrics.
>
> Unit Manager, Wire Rod Casthouse

An important consequence of this structure was that each subunit and each operator was expected and incentivized to focus primarily on their own performance metrics. Therefore, as long as the operators and subunits were measured on performance metrics that were related to their tasks in isolation, they had little incentive to optimize their processes for their neighbor.

> A person has focus on his own performance metrics. This is what he is being followed up on, right. He works on his own things, and then he forgets that it is related to his neighbor's problem.
>
> Unit Manager, Wire Rod Casthouse

This narrow focus had a negative influence on the problem identification process, as it leads to a lack of overall understanding of the process. This was problematic because of the many technical interdependencies in the wire rod production line. As shown by this case, identifying the real problem in an interdependent technical system required someone had to sit down and take an overall perspective, because the root cause was deeper in the system than just one specific operator's responsibility. When the individual operators were not incentivized to do so, because of detailed individual performance metrics, this responsibility rested solely on the unit manager.

4.3.3.2 Network

Introduction of the new emulsion required specific knowledge of emulsion technology. Within Hydro this particular knowledge was not situated within Primary Metal, but in the R&D unit within Rolled Products, located in Bonn. The rest of the casthouses within GFOS had no use for this knowledge, and therefore there were no designed horizontal linkages in Hydro's organizational structure that connected the casthouse at Karmøy to R&D Bonn. Consequently, the production unit at Karmøy was not aware of the emulsion technology developed by R&D Bonn, and likewise, R&D Bonn was not aware that the wire rod casthouse at Karmøy was in need of a solution like their technology.

It seems then, that in a relatively large organization like Hydro, where the different areas of expertise are spread across different technology units and divisions, situations may occur where the relevant technology is not organizationally close to the problem, making it hard to find the necessary knowledge and technology. Overcoming this situation in the emulsion project required a network that span across the formally designed organization structure and a form of knowledge about where knowledge and competence existed.

The unit manager had developed an extensive personal network through his career, primarily through employee transfer, and therefore he knew directly who to contact. According to the unit manager, himself, the lack of knowledge about where in the organization the competence on emulsion existed was one of the main reasons why this project was not initiated earlier.

> I think it is quite important when you work in an organization like Hydro that the managers have been around in the different business units. Suddenly you pick up something that relates to a future problem somewhere else, allowing you to use that competence later.

> Likewise, you will be able to find the necessary competence later, because you know where to find it. (...) The fact that we know where the competence in the different business areas is, where to find it, because we don't have that competence here. (...) To have a network, or to understand the importance of where the different competence in Hydro is, where you can ask for help, I think that is important. If it wasn't for that, we wouldn't have initiated this project, we would just have continued with what we did.
>
> Unit Manager, Wire Rod Casthouse

Interestingly, this case showed that a large personal network was not the only way to find the relevant knowledge in the organization. As shown by the email correspondence of the procurement manager, utilizing the existing links between other employees in the organization allowed him to reach out to parts of the organization that he did not personally know. Starting with the procurement manager for the rolling mill at Karmøy, he was forwarded to a larger rolling mill in Norway, and eventually to the research center for Rolled Products in Bonn. However, as the case also showed, finding knowledge in this way was more time consuming than knowing directly who to contact. Moreover, the unit manager's personal experience within Rolled Products was important to make the final decision of proceeding with the project and inviting the researcher to the wire rod casthouse.

4.3.3.3 Interface Between R&D and Operations

How the interface between the R&D unit in Bonn and operations at Karmøy was structured had a great influence on the process of integrating the new technology. The case showed that the interface between the two units varied at the different stages in the technology introduction process.

As explained in the previous section, there were no designed horizontal linkages between the R&D unit in Bonn, belonging to the Rolled Products division, and the wire rod casthouse at Karmøy, belonging to the Primary Metal division. Thus, the two units had to design these linkages themselves. A temporary interface between the two units was therefore set up. It consisted of two structural elements: an initial workshop and a project group, as shown in Figure 4.11.

The workshop held at Karmøy in the beginning of 2012 marked the start of the cooperation between the two units. This interdisciplinary workshop involved researchers from R&D Bonn, technical managers from Karmøy and the unit manager from Karmøy. The result of this initial workshop was that the body of understanding of the researchers was combined with the body of practice of the operating unit at Karmøy. The combination of the different knowledge forms made Karmøy able to communicate the changes

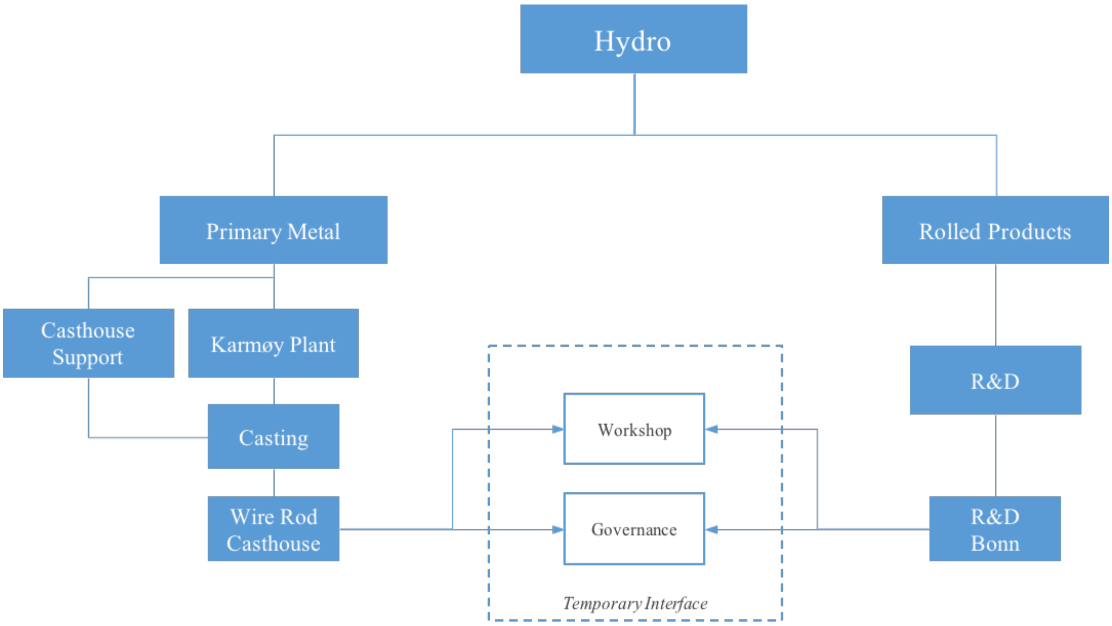

Figure 4.11: Organizational Units Relevant in Emulsion Project, Indicating the Interface Between R&D Bonn and the Wire Rod Casthouse

and improvements that were needed to be done to the technology in order to fit it to their production system. And it gave the research team from Bonn insight in the production system at Karmøy, and how it differed from a rolling mill, for which the new emulsion was originally developed. Thus, when the researcher had returned to Bonn, they made use of this insight to better simulate the actual operating conditions at Karmøy, and modify their technology accordingly. Effectively, the combination of knowledge enabled by the workshop allowed the body of understanding in R&D Bonn to be applied.

Compared to the first months when they were only communicating over email, the process greatly sped up once they had met in person through this workshop. This shows that a media rich form of communication greatly enhanced the sharing of knowledge between the two parties. This exchange of knowledge was important for the operating unit at Karmøy to understand that the new emulsion could mitigate their problems, and for the researchers to be able to make the correct modifications to the technology. Thus, this workshop was important for completing the process of finding a solution, as well as leading to the initial success of the integration process.

After the initial workshop, the unit manager created a project group responsible for integrating the technology in the production system at Karmøy. The project group consisted of a project manager from Karmøy, two researchers from R&D Bonn and a technical manager from Karmøy. While an effective structural element to facilitate the implementation, the project group lost much of its functionality when it was physically split up, and the researcher went home.

During the first weeks after the implementation of the new emulsion, the researchers from Bonn were present at Karmøy, and supported operations. The presence in operations together with the preparations that were made after the workshop seemed to have contributed to a very successful implementation of the new emulsion. However, while the initial implementation of the technology was successful, the technology was not successfully integrated yet. After the researchers left, problems started to occur. Both the operators and the technical managers expressed their dissatisfaction with the lacking follow-up from the researchers in the time after the implementation.

> You have close supervision during the first weeks, but after two weeks half of the competence you need leave. We did not have the right people here, of course we kept in touch over the phone. And after a month, all the competence was gone, and then we were left on our own. In the beginning it went just fine, but then it crashed. That was a very cumbersome time for us. Then I think there should have been a project manager from the R&D unit here for a year, or half a year.
>
> Technical Manager 2, Wire Rod Casthouse

According to the unit manager, this project and the responsibility for the technology was handed over to operations too early. The new technology had not shown stable production over a long enough period of time, as became evident when the problems started to occur three to four months after the technology was implemented in the production system.

> We didn't plan the operation phase, from my side. I might have underestimated the transfer from project to operations. That's something I have learnt.
>
> Unit Manager, Wire Rod Casthouse

The result of handing the project over to operations before the production process was stabilized was that when problems started to occur none of the researchers from R&D Bonn were physically present at Karmøy. This lead to limited technical support by the researchers, mainly because of the great physical distance between Karmøy and Bonn. Thus, the cooperation had to take place through emails and phone calls. This made it difficult for the researcher to fully get a grasp of the problems, as they could not observe them. Combined with limited body of practice about the production system at Karmøy, the researchers in Bonn were not able to come up with a solution to the problems caused by the new emulsion. Effectively, the project organization was broken down and lost most of it's functionality when the researchers left Karmøy.

Compared to the workshop and the part of the project where the researchers were present at Karmøy, lack of physical presence made it difficult to apply the body of understanding of the researchers in Bonn. Thus, this case showed that effective integration of new technology was influenced by the type of interface between R&D and operations. Specifically, the stability and the media richness of communication was important.

4.3.3.4 Incentives for New Technology

This case showed how the incentives given by Hydro to develop and make use of new technology influenced organizational learning driven by technology introduction. First, the senior researcher in R&D Bonn had the opportunity to conduct applied research and develop new emulsion technology because of central funding. Second, the technology had not been tested by anyone in Rolled Products, possibly because a lack of incentives to be the first to try new technology. Third, because wire rod casthouse experienced critical problems with their emulsion they had incentives to try the technology.

The senior researcher in R&D Bonn was given incentives to develop new technology, as he could qualify for financial support by the management of the R&D unit. It was because of this support program he was able to develop the new emulsion technology through a three-year research project. However, after the research project was completed in 2010, the new emulsion technology was not tested in operations until R&D Bonn was approached by the wire rod casthouse. In the meantime, he had not been able to get any of the rolling mills in Rolled Products to test his technology.

> They had been working on introducing the new emulsion in operations in Rolled Products for many years. But he [the senior researcher] had not found anyone who dared to try it.
>
> Unit Manager, Wire Rod Casthouse

It should be noted that we have no empirical data from the internal decision processes in Rolled Products, but a possible explanation may be that none of the rolling mills in Rolled Products had sufficient incentives to take the risk associated with testing the new emulsion technology. As shown by this case there was a great deal of risk associated with testing and integrating new technology. During this project it was operations at Karmøy that had to bear the risk associated with downtime and malfunctions if the new technology would turn out to not work at all. Thus, if none of the rolling mills in Rolled Products experienced similar problems with their emulsion they would have very little reason to try something entirely new.

The wire rod casthouse, however, had incentives to take this risk because they experienced a problem that they were unable to find any other solution to. They had an unstable production process and major HSE issues related to their current emulsion. Thus, there was also a risk associated with continuing with the old emulsion. This provided sufficient incentives to take the risk of testing the new emulsion.

When the new emulsion turned out to be a success, the emulsion project was awarded the Technology Development Innovation Award, and the project was therefore presented at a large annual company conference that included representatives from Rolled Products. As a result of this conference the new emulsion technology received increased attention from the other rolling mills in Rolled Products.

> When I presented the technology at the conference there were people from Rolled Products there, and suddenly they also wanted to try this.
>
> Unit Manager, Wire Rod Casthouse

This shows that as soon as the technology had a proven track record it became more attractive for the operational units in Rolled Products. When it had been proved to work the risk had been greatly reduced, and therefore the new emulsion received more interest.

4.3.4 Summary of Within-Case Analysis: Emulsion Project

Throughout this case analysis we have seen several ways in which the organizational structure has influenced organizational learning. In the emulsion project case organizational learning was driven mainly by four processes; developing technology, identifying the problem, finding and developing a solution and integrating the technology. Each of these processes were influenced by different structural elements. An overview of how the different structural elements influenced the learning processes is given in table 4.2.

Table 4.2: Structural Influences in Emulsion Project

Structural Element	Develop Technology	Identify Problem	Find Solution	Integrate Technology
Performance Metrics		Detailed performance metrics lead to lack of overall understanding. Made it harder to identify the underlying problem.		
Network			Unit manager's extensive network within, and experience from, Rolled Products enabled the wire rod casthouse to find a solution in another division.	
Interface Between R&D and Operations				The initial workshop enabled the researchers to make the necessary adjustments to the emulsion technology before implementation. Detached project organization reduced ability to combine body of practice and body of understanding. Made it hard to develop a joint solution to the problems that occurred after implementation.
Incentives for New Technology	Central funding allowed senior researcher in R&D Bonn to conduct three-year applied research project.			Lacking incentives to counter the risk associated with testing new technology made it hard for senior research to get his technology tested in Rolled Products. Large problems with current technology provided the wire rod casthouse with an incentive to test the new emulsion technology.

4.4 Cross-Case Analysis

In this section a cross-case analysis of the two cases will be carried out. Through comparing the findings from each case we aim to gain a deeper understanding of the learning processes and the structural elements outlined in the preceding within-case analyses. Based on the results from the cross-case analysis we will develop a conceptual model to describe the structural influences on organizational learning during introduction of new technology. Thus, this section will answer the research question in two ways. First in relation to the empirical data and second on a conceptual level.

4.4.1 Organizational Learning During Introduction of New Technology

In section 2.2 we argued that organizational learning can be seen as a set of learning processes that take place in the organization, leading to an increase in knowledge. In the two cases studied we have identified a set of such processes that are particularly relevant for technology introduction. Here the relevant learning processes will be discussed and compared across the two cases to further our understanding of what they look like during introduction of new technology, and how they contribute to organizational learning. The processes will be reviewed in the sequence they took place during the cases, however it should be noted that this is not a sequential or stepwise model. To a large extent the processes also occurred in in parallel.

4.4.1.1 Technology Development

Both cases were characterized by a process of technology development. By this we mean a process in which the technology was developed and refined outside the operating environment. In both cases this was a fundamental requirement for technology introduction. However, there is a notable difference between the two cases. In the anode recipe project, technology development happened as part of the problem solving process in operations. An operational problem triggered the governance manager and the SPOC to look into anode recipes. The SPOC then built on existing knowledge within R&D to develop a new anode recipe, specifically for Sunndal. On the other hand, in the emulsion project, the new emulsion technology was developed independently of the operational problems at Karmøy. It was a result of several years of applied research conducted in R&D Bonn, completely independent of the wire rod casthouse at Karmøy.

Still, both types of technology development share some characteristics. In both cases, the need for a specialized R&D unit to be the center of technology development was prevalent. Development of new technology required an extensive body of understanding within the relevant scientific field. Achieving this was enhanced by having differentiated R&D units as it allowed the personnel within those units to specialize in specific scientific fields. Furthermore, both cases depended on applied research conducted in R&D. In the anode recipe case, the necessary research on anode recipe technology was already done, and existed within R&D. The technology development done by the SPOC was mostly a process of synthesizing existing knowledge, and use it to develop a recipe for Sunndal. In the emulsion case, the senior researcher both conducted the applied research, and then built on those results to modify the new emulsion for the wire rod casthouse.

In addition to the lack of necessary knowledge another reason that a specialized R&D unit was necessary for technology development was that operations simply did not have the time to prioritize these projects. As was clear from both cases operations are mainly concerned about keeping the production running, and reach their target measures. Thus, their focus was primarily short term, making it hard to complete a technology development project on their own. Personnel in the R&D unit, however had a more flexible schedule, and their workday was better fit to work with large projects.

4.4.1.2 Problem Identification

Problem identification was found to be another important driver of organizational learning. Identifying problems and poor performance in operations initiated the technology introduction processes. Moreover, understanding the cause of the problems was a critical learning process in order to develop and introduce the right technology. Therefore, operations' ability to detect and understand technical problems was important. Both cases showed that in a complex technological environment the cause of the problem can be difficult to identify. The production systems have many interdependencies, and the visible issues may be caused by problems somewhere else in the system.

Furthermore, both cases showed that if the problem is not sufficiently understood, it was hard to find the right technical knowledge in the organization, and develop the right technology to solve the problem. In the anode recipe case, it was critical to understand that the crack problems were related to the anode recipe, and not any of the other quality parameters they were used to work with. In the emulsion case it was critical to see beyond the large number of smaller problems and process variation, and instead direct all focus on the emulsion. Until that was done, no progress was made in neither of the cases.

4.4.1.3 Finding and Connecting Resources

Introduction of new technology depended on finding and connecting the required resources in the organization. This included knowledge, skills and technological artefacts that were used to solve problems and improve performance in operations. Both cases have shown that relevant expertise and knowledge may be located far away, both geographically and organizationally, from where it is needed. Finding the necessary knowledge was important to get both projects started. In these situations, having knowledge about where in the organization relevant expertise and knowledge were located proved to be of great importance.

In the anode recipe case, three separate parts of the organization contributed with important knowledge to the project: the operating staff at anode production, the researchers within PMT, and the engineer from the joint-venture plant. Thus, both finding and combining these resources to the project was a substantial process in its own. This work was largely facilitated by the governance manager in PMS. In this process his extensive knowledge about where knowledge and expertise within the organization resided was important. Similarly, the emulsion project also involved different parts of the organization. A notable difference here, however, was that there was no formalized structure to coordinate the cooperation between the wire rod casthouse and R&D Bonn. Thus, they had no governance manager with an overview of both areas. The effect was that the process of finding the relevant expertise was more challenging, and had to be managed by the operating unit themself. Still, this case exhibited the same characteristics in the sense that having knowledge about where knowledge can be found was of great importance.

4.4.1.4 Technology Integration

The process of integrating new technology was critical in both cases. It included both the initial implementation, adjusting the technology to fit the existing system, as well as solving the problems that occurred after implementation. In both cases, these processes were highly dependent on combining a body of understanding, represented by the researchers who had developed the technology, with a body of practice, represented by the personnel in operations. However, this combination happened with varying degrees of success across the two cases.

Before, and during, implementation both projects were relatively successful. By being part of the testing and problem identification at Sunndal, the SPOC gained a good understanding of the problems and the current anode recipe, and was therefore able to develop a new and better recipe. Similarly, through the initial workshop at Karmøy, the research team from R&D Bonn learnt about the wire rod production process and understood how their new emulsion technology could be adapted to work there. Thus, in both cases, the new technology was effective at solving the original problems.

However, both projects encountered other problems after initial testing and implementation of the new technology in operations. At Sunndal, the new recipe caused problems with maintaining the mass balance in the production system, and at Karmøy they were troubled by severe wear and tear on their rollers. With respect to the success in solving these problems, the two cases differed widely. In the anode recipe case, the mass balance problems were discovered already during the first test, and solved within a few weeks. In contrast, the problems at Karmøy were not discovered before several months after implementation, and they struggled with the problems for more than a year.

By looking at how the two cases differed in terms of combining body of understanding with body of practice a possible explanation of this difference in performance can be found. At Sunndal the SPOC functioned as a knowledge integrator. As a researcher from PMT she had access to a broad body of understanding regarding anode technology. Moreover, she spent much time physically present at Sunndal, talking to and learning from a broad range of operating personnel. Thus, she also gained access to a substantial body of practice regarding the operation of an anode production line. As a result of this combination she was able to get a good grasp of how the new technology impacted the existing production system and caused new problems, and thus make the necessary adjustments. In addition to being a knowledge integrator, the SPOC also functioned as a project manager. The effect of this was that her involvement extended far beyond the initial implementation. The fact that the SPOC, with her access to both body of understanding and body of practice, was present regularly until the process had stabilized was instrumental in solving the problems that occurred after implementation.

In contrast, in the emulsion case there was a lack of both a knowledge integrator and a project manager with the ability to effectively combine body of understanding and body of practice. Apart from the initial workshop and the weeks during implementation, the research team from Bonn was not particularly involved in operations at Karmøy. Moreover, none of the involved personnel at Karmøy gained considerable insight in the principles behind the new technology. Thus, when the problems surfaced, and the researcher had returned to Bonn, neither party had sufficient insight in the other party's knowledge to effectively assess the impact of the new technology on the existing. This made it much harder to solve the new problems.

4.4.2 Structural Influences on Organizational Learning

Having discussed what characterizes organizational learning during introduction of new technology, we will now discuss how the organizational structure influences this learning. In the within-case analyses a set of structural elements that influenced organizational learning were identified. In this section, the structural elements will be compared across the two cases. Through the comparison we aim to develop a deeper understanding of their influence on organizational learning.

4.4.2.1 Performance Metrics

Because of the complexity of the production systems, operations have to rely on a predefined set of metrics to measure and track the performance of the system. Keeping track of these measures allow them to discover deviations in performance, indicating when there is something wrong. Both cases have shown that employing such measures were critical for identifying the problem, but also that detailed measuring can lead problem identification down the wrong path.

In the anode recipe project, measuring the performance of each anode type, allowed the electrolysis to identify that one specific anode type, the Sunndal anodes, was causing the crack issues. However, the internal performance metrics used by anode production were not able to identify the source of the problems experienced by the electrolysis. This underlines the importance of understanding all aspects of the process and how it affects the neighboring processes in production.

Furthermore, as shown by the emulsion case, relying too much on a set of predefined metrics had an adverse effect on problem identification. This because the measures were broken down into individual parameters, and consequently there was no one who saw patterns in the overall process. Thus, the narrow focus lead to a reduced understanding of the relation between the different problems, and identifying the root cause of the problems became difficult. Thus, even though the measures are valid and well defined, if they are too detailed and considers sub processes in isolation, they may not contribute to an overall problem identification.

4.4.2.2 Employee Transfer

We have seen that an important characteristic of organizational learning during technology introduction is the need to find and connect resources across the organization. This required knowledge of where the different types of knowledge can be found. Both cases showed that this knowledge was possessed by a few key employees. Moreover, a common characteristic among these people was that they had acquired the knowledge about where knowledge is through employee transfer.

In the anode recipe case, the governance manager had previously held a technical position at the anode production at Sunndal, and through his position in PMS he was frequently meeting technical employees from different areas of the organization. This gave him a broad insight in where people with relevant knowledge and expertise could be found. Similarly, the unit manager at the wire rod casthouse had prior experience from Rolled Products, and therefore he had knowledge of the R&D unit in Bonn. This shows that when people are moved around, expanding their network in the organization, they gain knowledge of the various areas of technological knowledge that exist in the organization. Thus, in both cases, employee transfer had a positive influence on the organizational learning process. Specifically, through enabling faster and easier localization and access to the relevant body of understanding.

4.4.2.3 Interface Between R&D and Operations

As argued earlier, combining body of understanding and body of practice was important to successfully integrate technology into operations. The studied cases showed that the interface between operations and R&D played an important role in facilitating this combination.

In the anode recipe case the interface was made up by the SPOC. As a liaison position, one of her responsibilities was to handle the flow of communication between anode production and PMT. Effectively, she was therefore responsible for making the body of understanding in R&D available to operations. Another responsibility she had in this liaison position was to assist operations in carrying out technology introduction projects, as well as regular follow up. As a consequence of being frequently present in operations and interact with a broad range of personnel there, she gained a considerable body of practice regarding anode production. Thus, having a liaison position in the interface between R&D and operations lead to a form of cooperation that ensured that someone had access to both bodies of knowledge. As argued earlier, this enabled effective combination of both bodies of knowledge.

The effect of having a formalized liaison position like the SPOC in the interface becomes even more visible when contrasting the anode recipe case with the emulsion case. In the emulsion project there was no organizationally designed interface, and the structure used to facilitate collaboration between the wire rod casthouse and R&D in Bonn was only temporary. When the collaboration involved physical presence, as in the workshop, the two units seemed to effectively exchange knowledge. However, after implementation, when the project group was geographically split up it was harder to effectively exchange knowledge. This made it difficult to develop a common solution to the problems that occurred after implementation. Without fully understanding how the new technology worked, and how it impacted the existing production system, it was hard for both parties to solve the new problems it created.

4.4.2.4 Governance Function

The anode recipe case exhibited an interesting structural characteristic in the form of the governance manager. An arguably positive influence from the governance manager was towards the identification and connection of resources. As a third-party responsible for allocating money to technology introduction projects, he was in a unique position to call in resources from PMT and the operating units to workshops, and direct attention to a specific technological issue. Moreover, his extensive network within the organization, which was partially built through this position, gave him knowledge of, and access to a broad range of relevant knowledge. He made use of this network to connect the relevant resources. Thus, having a person in the organization who had formal power over some of the decision process between the R&D unit and the operating unit, together with an extensive knowledge about where the relevant knowledge resided within the organization, was shown to have a positive influence on the organizational learning process in the anode recipe case.

In the emulsion case, since the problems arose in one division and the solution resided within a different division, there was no governance manager spanning across the involved units. Therefore, operations at Karmøy had to manage the finding and connecting of resources themselves. Because the unit manager had an extensive network, and previous experience from Rolled Products this worked out fine in this particular case. However, given a situation where the unit manager at the wire rod casthouse did not have the network he did have, things may not have worked out as good as it did. Thus, it can be seen as partially due to luck. In contrast, having a governance manager formalize the connection of resources, and reduce the dependency on coincidental network relations.

4.4.2.5 Incentives for New Technology

The development and integration of new technology were identified as important organizational learning processes. The success of these processes were, as already discussed, dependent on the interface between R&D and operations. Another structural element that indirectly influenced the success and existence of these processes were the incentives embedded in the organizational structure. Specifically we mean how R&D's projects are funded and to what extent operations are incentivized to try out new technology.

First, the funding of R&D's projects is a determinant for the existence of technology development. Certain technological developments require research that do not immediately produce implementable technology for operations. Yet, this research increases the body of understanding within the organization, which at a later point in time may be useful for operations. Both cases showed examples of this. In the anode recipe case, one of the sources of knowledge about anode recipes were internal technology reports, written on the basis of research conducted by researchers within Hydro several years ago. In the emulsion case, the new emulsion technology itself was developed through an applied research project in R&D Bonn. These forms of research were not necessarily easy to finance from operations' point of view as the immediate benefits were not clear, and because such research have the chance of not producing any useable results. Thus, this form of research was dependent on a form of central funding.

However, there are downsides to central funding. It was clear from these cases that integration of new technology required close collaboration between R&D and operations. This was necessary to ensure that the developed technology was useful for operations in practice, and it was necessary to overcome the inevitable obstacles associated with integrating a new piece of technology into an existing operating environment. Thus, R&D could not operate in isolation. Therefore, requiring R&D to acquire a portion of their funding from operations, created incentives for R&D to work closer with the operating units. As one of the informants in the anode recipe case mentioned, when the funding of PMT shifted to this model, operations were more frequently approached by PMT. In the emulsion case, when the wire rod casthouse found the emulsion technology, the project to develop it was already completed, and the central funding to the emulsion technology was spent. Through additional funding from operations at Karmøy, a research team could be brought to Karmøy, and several more hours of work could be done to adapt the technology to the wire rod production. Thus, funding of R&D from operations had a positive influence on development and integration of technology.

Another important discussion can be made about to what extent the plants were incentivized to actually try new technology. As was clear from the cases, organizational learning was greatly increased when the plants were involved in development and integration of new technology. However, introducing new technology comes with a great deal of risk, and it is therefore not necessarily the case that operations are willing to try new technology. The emulsion case showed an example of this. The development of the technology was completed a year before the people at Karmøy approached R&D Bonn. In this period none of the rolling mills in Rolled Products, for which the technology was originally intended, had shown any interest in testing it. As long as their current solutions worked sufficiently they had little interest in taking the risk of testing something new. However, the wire rod casthouse was in a situation where production stops were already a fact, and therefore had much stronger incentives to try the new technology.

4.4.3 Conceptual Model for Structural Influences on Organizational Learning During Introduction of New Technology

In this section we will look beyond the specific details of each case, and develop a conceptual model for how organizational structure influences organizational learning. By this we will provide an answer to the research question at a conceptual level. The model is illustrated in figure 4.12. It consists of three parts. First, the model indicates the organizational units relevant for the introduction of new technology (dark blue boxes). Second, it shows the different learning processes that take place during introduction of new technology (light

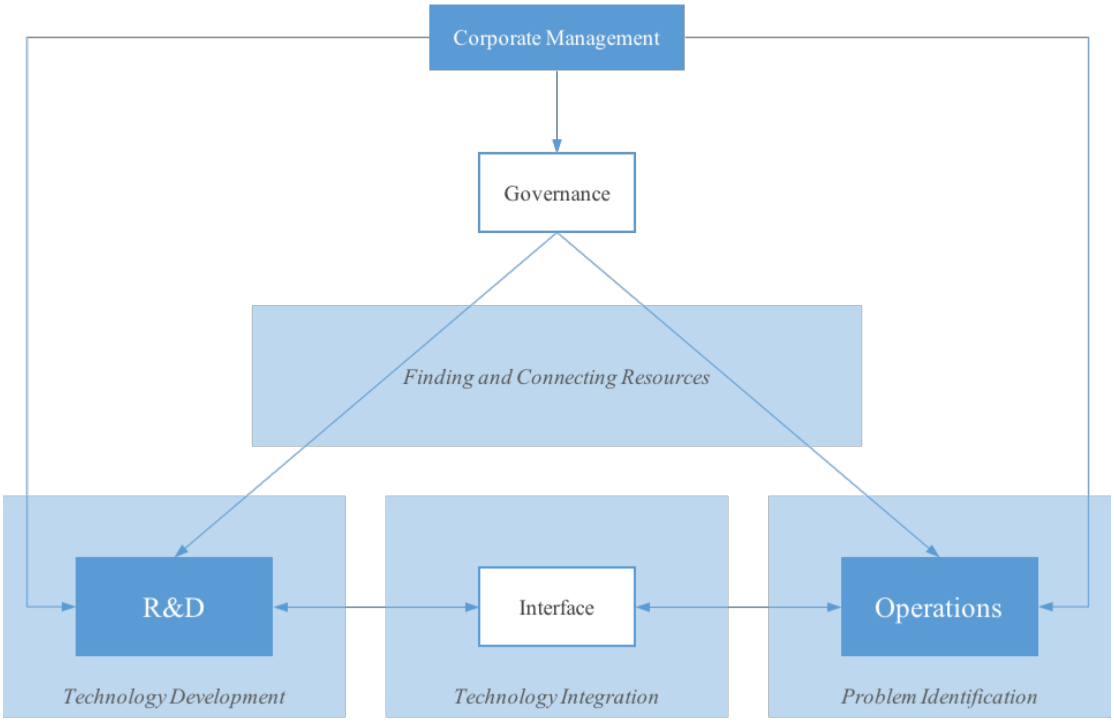

FIGURE 4.12: Conceptual Model for Structural Influences on Organizational Learning

blue boxes). Third, it outlines the structural elements that integrate the organizational units (lines).

Two organizational units are particularly relevant during introduction of new technology, and constitutes the cornerstones of our model; *operations* and *R&D*. Several structural elements in the organization contribute to the integration of R&D and operations. First is the *interface* between the two units. Second is the *governance* of resources related to technology introduction. Lastly, are the instructions and incentives given by the *corporate management*. Furthermore, the model conceptualizes organizational learning during introduction of new technology as driven by four different processes: *technology development*, *problem identification*, *finding and connecting resources*, and *technology integration*. As illustrated, each of these learning processes are influenced by the organizational structure. Each of these influences will be described in the following.

Technology development is influenced by the structural design of the R&D unit and the funding of it. Establishing a functionally differentiated R&D unit enables specialization in specific scientific field, building necessary body of understanding to develop new technology. Funding from operations incentivizes R&D to develop technology that solves specific problems, but some portion of central funding is necessary to ensure that R&D develop new knowledge and technology through long-term research projects.

Problem identification is influenced by the performance metrics defined by the organization, as well as the interface between R&D and operations. Defining the right performance metrics assist in discovering problems, but when performance is broken down and measured at a high level of detail, seeing the bigger picture and understanding the real cause of the problems is more difficult. The existence of a formalized link to R&D enables operations to access their body of understanding which can provide new insight in problem identification.

Finding and connecting the relevant resources that exist across the organization becomes challenging by having a differentiated structure. However, a governance function can mitigate these challenges. Having a governance function with an extensive overview of available resources in the organization facilitates the connection of operational problems with technological solutions. By letting the governance manager have some formal authority, the relevant resources can be connected through meetings and workshops. This process can also be facilitated by having managers in operations that, through a broad network, can find and reach out to the relevant technical resources on their own.

Technology integration is influenced by the interface between R&D and operations. Formalizing the interface in the form of a liaison position based in R&D, facilitates the combination of body of practice and body of understanding that is needed to integrate new technology into operations. As the liaison position is freed from operational pressure, this position is also well fit for managing the integration process. When the interface is not clearly defined no one is responsible for combining knowledge from the two units, making it harder to integrate the new technology.

Thus, by influencing the four different learning processes, the organizational structure influences organizational learning as a whole. As the model attempts to show this influence is multifaceted, but some overall characteristics can be drawn. The first is that formalized integration mechanisms employed to coordinate the cooperation between R&D and operations positively influence the organizational learning processes. It facilitates distribution of knowledge from R&D to operations, and ensures that required resources are allocated to joint projects. Formalization of these functions reduce the need to rely on personal networks and coincidental meetings. Second, a dual funding structure of R&D ensures that the technology developed is in line with operational needs, while at the same time giving R&D the flexibility to do more than just solving short term technical problems in operations. Applied research projects also contribute to organizational learning by increasing the body of understanding within R&D.

Discussion 5

In the preceding cross-case analysis the research question was answered. First, in terms of the specific details of the cases. Second, in more general terms, through the development of a conceptual model. In this chapter these findings will be discussed in light of the reviewed literature. We will outline to what extent our findings correspond to prior research, and to what extent they differ.

5.1 Organizational Learning During Introduction of New Technology

In this thesis organizational learning has been studied during introduction of new technology. By limiting our scope to introduction of new technology we have been able to go deeper into the phenomena and discuss the specific learning processes that are most relevant for organizations within this scope. Our findings suggest that organizational learning taking place during introduction of new technology, in some areas, is distinctly different from what previous literature suggests. In this section we will show how the different learning processes - technology development, problem identification, finding and connecting resources, and technology integration - relates to, and differ from, previous literature within the field.

5.1.1 Technology Development

Technology development has not been included in any of the general models on organizational learning. Huber (1991) outlines knowledge acquisition as one group of sub processes related to organizational learning. Within this group he gives a broad overview of different sources to knowledge, but the development of technology is not included here. This gives an impression that knowledge can always be acquired from somewhere, either externally or internally. With respect to introduction of new technology, our findings show that this view is insufficient. In both cases, technology development was one of the main sources of knowledge and organizational learning. This shows that technological knowledge cannot always be acquired, but must be generated through a complex process of research and development, which requires a substantial body of understanding in the relevant scientific field.

Given that the technology is readily available, operations can acquire this knowledge in the sense described by Huber (1991). However, this presuppose a process of technology development. Thus, we argue that when researching organizational learning in organizations where technology plays an important role, technology development should be included as an important organizational learning process.

Another stream of research within organizational learning that overlooks the importance of technology development as a distinct learning process is the models of experiential learning (e.g. Argote and Epple, 1990; Argote and Miron-Spektor, 2011). This theory provides a good explanation for how organizations can get incrementally better by repeatedly performing routine tasks. However, as our findings show, development of technology is by no means a routine task. As already pointed out, technology development requires the organization to have a substantial body of understanding within a specific field, which cannot be acquired solely by experience. It is primarily through research and development new technological knowledge and artefacts can be generated - not by repeatedly using already known technology.

This argument should be viewed in relation to Levinthal and March's (1993) critique of experience as a source of learning. They argue that experience can lead to a myopia of learning, causing the learner to have a short term perspective and favor those effects closest to himself. In order to develop new technology, it is instead necessary to have a long term perspective, as it may take several years and that outcomes are not certain. Additionally, since the technology developed will be put to use somewhere else than where it is developed, the researchers cannot favor effects close to themselves. Therefore, learning from experience is not suitable to achieve effective development of new technology.

Important in managing the time perspective of technology development is the structuring and funding of R&D. As argued by Coombs (1996), the R&D unit should be partially funded and controlled by the corporate part of the organization in order to ensure long term research. Our findings support this proposition. Central funding incentivized applied research that lead to the development of new technology. In contrast, it seems unlikely that operations would finance such long term projects because of their short term perspective and reluctance to take risk, even though the technology proved highly valuable for them in the end. Furthermore, Coombs (1996) argues that the other part of the funding and control of the R&D unit should be in the hands of the operating units, as this ensures that the developed technology is in line with the needs in operations. This too was clearly supported by our findings. In fact, formalizing the relationship between R&D and operations with a clearly defined liaison position, as well as a governance function lead to technology development that was closely tailored to operational needs.

5.1.2 Problem Identification

In their theory of organizational learning, Argyris and Schön (1996) argue that when members of the organization experience a mismatch between expected results and actual outcomes they inquire into it. In relation to introduction of new technology, this inquiry is particularly relevant. Our findings have shown that the process of identifying and understanding problems, can be difficult and complex when related to a system of interdependent technological artefacts. The reason is that the observed problems are often just symptoms of an underlying issue. Therefore, the inquiry must uncover the relationship between the symptoms and the problem. This relationship is of a technical nature, and understanding it often requires knowledge of the specific technological artefacts, the scientific principles behind the technology, or a combination of both.

5.1.3 Finding and Connecting Resources

Our findings support Huber's (1991) claim that organizations often do not know what they know. This seems to be particularly true for differentiated organizations where different units are specialized in specific technological areas. Then, it becomes difficult for operations to maintain an overview of where the relevant knowledge exists. The implication of this challenge is that technology introduction requires an extensive effort in finding the relevant resources within the organization.

In relation to knowing where knowledge exists, Huber (1991) suggests that internal employee transfer facilitates coupling of those in need of specific knowledge with those who have it. This suggestion is also largely supported by our findings. Employee transfer was found to positively influence the process of finding and connecting resources. In addition, our findings suggest that another way the organization can overcome the challenge of knowing where to find knowledge is by having a dedicated governance function that maintain an overview of the units that develop and possess knowledge, and the operating units that are in need of it.

5.1.4 Technology Integration

Iansiti (1995) argues that one must carefully consider the impact of a new technology on the existing technology and reconfigure new technology in order to make it fit the existing technological system. Furthermore, Pisano (1994) argues that cross-functional integration between R&D and operations is important for technology integration. These propositions are largely supported by our findings. Our findings show that fully understanding the impact of new technology on the existing system requires that the body of understanding of R&D is combined with the body of practice from operations. The success of this combination is determined by the interface between these two units. The interface provides operations with access to the body of understanding within R&D, as well as it gives researchers from R&D access to the body of practice accumulated in operations. Thus, the interface between R&D and operations facilitates the cross-functional integration suggested by Pisano (1994).

The importance of combining body of understanding with body of practice corresponds well with Pavitt's (1998) argument that the organization must develop a body of practice that can link the body of understanding to useful technological artefacts. The linking suggested by Pavitt is found in the job done by the SPOC.

Furthermore, Pavitt (1998) argues that experience, in combination with experimentation and exchange of information, is important to build a body of practice about a specific production process. Thus, the model of experiential learning presented by Argote and Miron-Spektor (2011) is applicable, and important, to understand how the body of practice is built. Our findings show that the operators, through many years of performing routine tasks in operations, built a substantial body of practice about the production process. By transferring some of this body of practice to the researchers they were able to better assess the impact of new technology on the existing system.

Regarding the process of combining and transferring different forms of knowledge, Polanyi's (1969) reflections of formulation and interpretation of knowledge provide useful insight. In order for people to effectively communicate their knowledge, particularly when their backgrounds and prior knowledge is very different, a media rich channel is required. Our findings clearly show that the media richness in the interface between R&D and operations was an important determinant for how well they were able to exchange and create new knowledge together. Specifically, we found that when interaction in the interface happened face-to-face the sharing of knowledge was most effective, as suggested by Daft and Lengel (1986).

Related to technology integration is also Pisano's (1996) discussion about learning before doing and learning by doing. The concept of learning before doing explains the benefit of the process where new technology is tested in laboratories and pilot facilities. By simulating the actual operating conditions as close as possible, the researchers were able to readjust the technology before implementing it. However, our findings show that because of the complexity in the technical system it may take some time before the effects of the new technology becomes visible. Consequently, it was not possible to predict all cause and effects of the new technology beforehand. Therefore, as also suggested by Pisano (1996), some learning must inevitably happen by doing.

5.2 Rethinking the Influence of Organizational Structure

In the case analyses we have outlined several ways in which structure influences organizational learning. Here we will discuss these influences in relation to existing literature, and develop an argument that elements of mechanistic structure have a positive influence on organizational learning during introduction of new technology.

The proposition that mechanistic structure can positively influence organizational learning stands in contrast to what most prior literature on organizational learning have suggested. Drawing from the innovation literature (e.g. Burns and Stalker, 1961), the argument has been that mechanistic structure tends to impose limitations on employee's ability to be creative, innovate and therefore also their ability to learn. Consequently, moving away from mechanistic structure towards an organic structure has been proposed to enhance organizational learning (e.g. Fiol and Lyles, 1985; Meyer, 1982). However, we have found that organizational learning is not just possible, but in fact enhanced, with a mechanistic structure. Specifically, there are two elements of mechanistic structure that positively influenced the organizational learning processes. First, the functional differentiation of a specialized R&D unit. Second, a formalized set of integration mechanisms to ensure effective cooperation between R&D and operations.

First, as our discussion of organizational learning during introduction of new technology suggests, technology development is an important learning process that requires a substantial body of understanding within the organization. According to Pavitt (1998) this type of knowledge is based on competencies in specific technological fields. Our findings show that establishing this form of knowledge requires highly educated personnel, devoted to research and development. Moreover, both cases showed that in order to specialize in the relevant technological fields, separate R&D units were set up to develop technology for different business areas. This fits well with Mintzberg's (1983) argument that the highest level of specialization is achieved by establishing functionally differentiated units. Structuring the organization in this way is indeed more mechanistic than organic, but it clearly enhanced organizational learning by facilitating technology development.

Furthermore, as a contributing process to organizational learning, technology development in specialized R&D units is distinctly different from the way organizational learning has been conceptualized by the experiential learning literature (e.g. Argote and Miron-Spektor, 2011). During introduction of new technology, organizational learning did not result from repeated performance of the same tasks and an accumulation of experience. Instead, it resulted from the specialized body of understanding and an active decision to link this with a body of practice to create new and improved technological artefacts. Thus, technology development cannot be substituted by experiential learning methods. The implication is that experiential learning fails as a general model of organizational learning. In fact, it provided little insight in the organizational learning studied in these cases.

While our findings indicate that a functionally differentiated R&D unit positively influenced technology development, they also show that a high level of task specialization within operations negatively influenced problem identification. When both tasks and associated performance metrics were broken down to small parts, individual operators were at risk of losing both track of, and incentives to pay attention to the overall state of the system. Thus, reducing their ability to understand underlying problems, and instead leading them to focus on short term mitigation of symptoms.

Second, the case analyses have uncovered several integration mechanisms that positively influenced organizational learning. The interface between R&D and operations, that was found critical for successful integration of new technology, was also found to be most effective when defined through formalized and stable positions. Furthermore, the process of finding and connecting resources was found to be positively influenced by a formalized governance function of the cooperation between the two units. Both of these mechanisms were designed and appointed from the top of the organization. Thus, through the use of authority, hierarchical elements were employed to facilitate organizational learning. Arguably, these integrating mechanisms are mechanistic in nature, but still they showed to have a positive influence on the organizational learning processes during introduction of new technology.

Thus, in sharp contrast to what most literature suggests about the structural influence on organizational learning (e.g. Fiol and Lyles, 1985; Meyer, 1982), our findings show that organizational learning was positively influenced by formalization and authority. Finding and connecting the relevant resources as well as integrating the technology was in fact in fact harder to achieve when coordination between R&D and operations was not formalized. Thus, moving towards a more organic structure by reducing formalization would in these cases have hampered organizational learning. This means that one should be very careful about making implicit assumptions that all organizations learn better with an organic structure.

A possible explanation of why these hierarchical elements does not limit organizational learning can be found by looking to Adler and Borys (1996). Their concept of the enabling bureaucracy suggests that if the formalization supports and allows employees to better perform their function, rather than coercively enforce compliance, bureaucracy can have a positive impact. This idea resonates well with our findings. Both integrative positions, while formally defined from the top of the organization, were intended to help operations perform better, and were carried out more as an optional service rather than an enforced control. For example, the formalization of a liaison position lead to stability in the interface between R&D and operations, as well as a deeper commitment from the R&D unit. All of which gave operations better access to technological knowledge and artefacts that helped them solve their problems and improve their performance.

Thus, our findings regarding the structural influences on organizational learning show that all four of the learning processes relevant to the introduction of new technology may be positively influenced by elements of mechanistic structure.

Conclusion 6

The following research question was proposed in the introduction:

> *How does organizational structure influence organizational learning during introduction of new technology?*

The thesis addressed this question by first developing an understanding of the relevant organizational learning processes during introduction of new technology, and second by outlining how structural elements influence these learning processes.

Four learning processes are particularly relevant during introduction of new technology: technology development, problem identification, finding and connecting resources, and technology integration. First, the process of technology development is a fundamental requirement for introduction of new technology, because it generates new knowledge and technological artefacts. Second, understanding the root cause of the problems is important for problem identification as this is necessary to develop and introduce the right technology. Third, finding and connecting the resources depends on having knowledge about where the different types of knowledge resides in the organization. Fourth, the process of technology integration depends on a combination of body of understanding and a body of practice, as both types of knowledge are necessary to assess the impact of the new technology on the existing system.

Each of these learning processes are influenced differently by different elements of the organizational structure. Technology development is positively influenced by having a differentiated R&D unit. Funding from operations incentivizes R&D to develop technology that solves specific problems, while central funding incentivizes R&D develop new knowledge and technology through long-term research projects. Next, problem identification is influenced by the way corporate management measures performance in operations. When a problem is identified, finding and connecting resources becomes challenging by having a differentiated structure. However, having a governance function with an extensive overview over R&D and operations positively influences this process. Lastly, technology integration is influenced by the interface between R&D and operations. Formalizing the interface in the form of a liaison position based in R&D facilitates the combination of body of practice and body of understanding that is necessary to successfully integrate new technology.

Thus, by influencing the four different learning processes, the organizational structure influences organizational learning as a whole. In an organization with functionally differentiated R&D and operations, formalized integration mechanisms are needed to coordinate the cooperation between these two units. Formalization of these integration mechanisms reduces the need to rely on personal networks and coincidental meetings for the right knowledge to be found. Furthermore, in order to ensure that the R&D unit develops new technology that is immediately valuable to operations, R&D should be partially dependent on funding from operational units.

Based on these findings two arguments were made in relation to existing theory. First, previous models of organizational learning, and experiential learning in particular, do not sufficiently explain organizational learning that takes place during introduction of new technology. Specifically, the process of technology development is an important contributor to organizational learning that cannot be explained by experiential learning models. Second, contrary to what prior literature suggests regarding the structural influence on organizational learning, our findings showed that elements of mechanistic structure can be beneficial for organizational learning. Specifically, formalization of coordination between R&D and operations positively influence organizational learning processes that span across both units, such as the integration of new technology.

6.1 Limitations

The boundary condition for our study of structural influences on organizational learning has been the introduction of new technology. Thus, the generalizability of our findings are limited to organizations undertaking projects to develop and introduce new technology. However, whether or not our findings can in fact be generalized to other such cases is subject to a set of methodological limitations.

Most importantly, our study is based on two specific cases in one specific case company. A thorough understanding of the processes taking place within this company has been established, and we have attempted to extract the core of these processes, seeking to avoid case-specific details. The comparative design is likely to have helped in this process (Eisenhardt, 1989; Yin, 2009).

Thus, it seems reasonable that our findings are transferable to other cases of technology introduction within the case company.

To what extent our findings are transferable outside the case company depends on whether firm and industry specific factors have been sufficiently accounted for. In particular, certain characteristics of the case company are important. First, a key assumption in our arguments is that an extensive production system constructed from interdependent technological artefacts is critical for the organization to perform its main task. Second, our model is developed around the assumption that those who operate such production system have not created it themselves, and are unable to make fundamental changes to the production system. But rather that the technology employed in operations is of such advanced scientific character that it must be developed and modified by specialized personnel. Lastly, central to our argument is that these specialized personnel are located in functionally differentiated units. Thus, if all three of these assumptions hold in another organization, it seems reasonable that our findings are transferrable.

Another important limitation is that both sampled cases are examples of problem-driven technology introduction. In other words, technology was introduced in order to solve a problem experienced by operations. However, technology can also be introduced as part of a more general effort to improve performance, and not initiated by operations themselves. This is an important distinction that may have implications for what learning processes that are relevant, and how they are influenced by the organizational structure. For example, finding and connecting resources may not be as important if technology introduction is initiated by R&D. Thus, all of our findings may not be transferrable to variants of technology introduction that are not problem-driven.

6.2 Suggestions for Further Research

Highlighting the important limitations of our study has also indicated where the need for further research is most prominent. First, similar studies in other firms and industries is necessary to strengthen the transferability of the findings presented here. Second, other variants of technology introduction than problem-driven should be studied to get a broader understanding of organizational learning during introduction of new technology. Lastly, as showed by this thesis, new insight was developed by limiting the scope of our inquiry to technology introduction. Similarly, new and deeper insight can possibly be gained by studying organizational learning in other well defined scopes. For example, it is reasonable to expect that the relevant learning processes, and even more so the influence of organizational structure, will differ greatly in organizations where technology plays a less important role.

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