# On Particle Accelerators and Timber-houses -How Network Dependencies Condition the Transfer of Technological Knowledge

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## INTRODUCTION

The importance of knowledge for firms and in economic development has been stated by many scholars (Schumpeter 1934, Penrose 1959, Marshall 1965, Nonaka & Takeuchi 1995, Håkansson & Snehota 1995). Håkansson and Snehota (1995) do, for example, claim that the combined knowledge of those taking part in a firm can be regarded as one of the firm's main assets. Just as economic development can be described as consisting "primarily in employing existing resources in a different way, in doing new things with them, irrespective of whether those resources increase or not" (Schumpeter, 1934:68), so can new knowledge be defined as new combinations of old resources and old knowledge. The distinction between new and already existing knowledge therefore becomes blurred; but why be concerned about the innovation value in a solution if it works just like – a solution? As interesting as the notion of knowledge creation is that of knowledge transfer. This concept has a strong appeal because of the possible gains. Why invent the wheel twice?

Based on two empirical studies the issue of transfer of technological knowledge is discussed further in the article. Both studies revolve round the problem of transferring technological knowledge, and both cases point at some of the difficulties with this transfer. There are also, however, great differences between the cases. One of the cases discusses transfer of "high-tech knowledge", while the other could be seen as more of "low-tech knowledge" transfer. The first case deals with the problems of formalising technology transfer from CERN, the European Laboratory for Particle Physics, to industry in primarily Europe; while the other depicts the transfer of knowledge within the construction industry, and more specifically the knowledge of building multi-storey timber houses, and how attempts were made to transfer this knowledge from the U.S. to Sweden.

The purpose of this paper is to discuss knowledge transfer from a network perspective, and to point out some of the implications this perspective has on the way knowledge can be perceived. The cases are used to describe transfer of knowledge situations and some of the results of the transfer.

Following this introduction, a short overview of the concept of knowledge in economic literature is given, thereafter the cases are presented one at a time, starting with the high-tech case and then moving on to the low-tech case. The theoretical background is then presented, and transfer of technological knowledge is discussed at some length. Finally, implications of the cases in relation to transfer of technological knowledge is analysed.

## The Concept of Knowledge in Economic Literature

The creation of new knowledge and of technological development was not a prime concern for classical economists, but rather treated as "disturbance" categories in their model. Under market mechanism, profit maximisation is enabled by the same fixed knowledge possessed by each firm, which in its turn is represented by price information. (Nonaka & Takeuchi, 1995:33) The Austrian school, on the other hand, tries to describe the dynamics of economic change focusing on "subjective" knowledge held by individual firms. In a criticism of the neo-classical approach Hayek claims that; "/…/there is something fundamentally wrong with an approach which habitually disregards an essential part of the phenomenon with which we have to deal; the unavoidable imperfection of man's knowledge and the consequent need for a process by which knowledge is constantly communicated and acquired."(Hayek, 1945:530) Hayek was also one of the first to argue for the importance of context-specific knowledge, an aspect of knowledge that we will return to later.

An other representative of the Austrian school, Schumpeter (1934), views new combinations of knowledge as the very driving force in the emergence of new products, production methods, markets, materials and organisations, that is in explaining the process of change in the economy as a whole. Whereas Schumpeter's main interest lays at the macro level of the economy, Penrose (1959) tried to explain the mechanisms behind the growth of individual firms. In doing so she pointed out the importance of experience and knowledge accumulation within each firm. She viewed the firm as "both an administrative organisation and a collection of productive resources, both human and material" (1959:24). According to Penrose, it is never the resources themselves that are the inputs in the production process, but only the services that the resources can render. These services are viewed as a function of the experience and knowledge accumulated within the firm, and thus firm specific. In essence, the firm is a repository of knowledge. The relativistic view of resources, where the value depends on the knowledge of how they can be used, is another aspect that will be dealt with in this article.

Based on similar assumptions regarding resource value, but using a somewhat different angle to the problem of knowledge creation and technological development, many scholars have emphasised the need of interaction in order for new knowledge to emerge (Alchian & Demsetz 1972, Lundvall 1988, Håkansson & Snehota 1995). Based on an assumption of heterogeneous resources (Alchian & Demsetz 1972) they argue for the impossibility of knowing in advance the outcome of a development trial. Alchian and Demsetz allege that resource combinations have to be tried out in "teamwork", whereas Lundvall asserts that the heterogeneity assumption puts experimental learning in focus. In the same spirit Håkansson and Snehota claim that; "Joint learning can be accomplished through interaction between resource providers and users" (1995:135).

The core concept of this paper is thus knowledge, and in particular technological knowledge, in relation to resources. Even more specifically, the paper deals with technological knowledge in relation to transfer. Before the concepts are discussed and the problem of knowledge transfer is examined, however, the two cases will be presented. Then the theoretical underpinnings for the paper, as well as for the cases, will be presented, and the concepts of knowledge, transfer and translation discussed.

# HIGH-TECH: KNOWLEDGE TRANSFER FROM CERN TO INDUSTRY[248]

## Introduction

Since the 1970s, the demand for basic science to be useful has increased. Researchers doing basic research often have to motivate their research by stressing the direct or indirect use for society. There is also a demand from politicians, more or less explicit, that all state-funded science should result in useful applications for industry. Do large research facilities have a role to play in industrial networks, that is, are they useful for industry? Should they be useful for industry, or do they have a completely different purpose, e.g. to create new knowledge, regardless of whether it is useful or not? Further, is it the applications that should be useful for industry, or does the potential knowledge transfer take place in other ways – for example through people, or indirectly?

This case discusses transfer of technological knowledge from one of these large research facilities, CERN (The European Laboratory of Particle Physics), to industry.[249] The aim is not to describe a success story, however, but rather to focus on how knowledge can be perceived, and how this affects the transferability. As this case is based on interviews both in Swedish firms and at CERN, an attempt will be made to discuss both how firms regard CERN and how they actually interact with the organisation. Further, how people at CERN perceive knowledge and how this perception in turn has an impact on the knowledge transfer will also be considered. Attempts to formalise technological knowledge in order to facilitate transfer have recently been made at CERN, and these attempts will be discussed, as well as examples of knowledge transfer.

## Firms' Perspectives on CERN

*"The people at CERN are always bragging about what an excellent reference customer CERN is, but who cares about what a bunch of crazy physicists do somewhere in Switzerland."*

When conducting interviews at Swedish firms[250], it soon became clear that firms which are suppliers to CERN in general do not regard the organisation as an important customer. Investments in a relationship with CERN do not pay. The reasons for this perception varied from firm to firm, however. Some people thought that CERN is too far away to be an interesting customer, as all their important customers were located in Sweden[251]. Others claimed that the orders are too particular, and that there is thus no incentive to try to get CERN as a repeat customer. To custom-design products is too costly. The volumes demanded by CERN are also considered too small – there are no economies of scale in the production. Some firms said that there is no use trying to maintain any contacts, because of the purchasing procedures at CERN. Thus, in most cases in this study, CERN is not important for

[248] The empirical material used in this case is part of a bigger material that is going to be used in a PhD thesis. So far, some 75 interviews have been made, both at CERN and in Sweden. The aim of the bigger study is to map out the relations between CERN and Swedish industry, and to see what Swedish firms "get out" of interacting with CERN.

[249] What is considered here is mostly high-tech technology, but at CERN, high-tech co-exists with basic, "every-day" technologies.

[250] All in all, more than 20 interviews have been made at fifteen Swedish firms. The firms differ greatly from each other; the number of employees range from ten people to several thousand, and they are active within very different industries. The common denominator is that they all have been suppliers to CERN at least once.

[251] For a thorough discussion on yhe impact of location on network performance, see Markgren (2000, forthcoming).

the Swedish firms, at least not as a direct customer. And perhaps this is no surprise – how can an organisation be world-leading in one specific area, and still be useful for the masses? There is no rule without an exception, however. But before we go into details about interaction between CERN and a specific firm, let us first turn to a short description of CERN.

**A Description of CERN**

CERN is located just outside Geneva, on the border between Switzerland and France, and the world's largest circular particle accelerator operate here today. No less than 20 European countries are members of CERN[252], but a far bigger number of nationalities are in reality represented at the site. Founded in 1954, CERN was it the beginning aimed at concentrating knowledge. One of the reasons for this was to reach a critical mass of physicists, so that research in nuclear physics (nowadays developed into particle physics) could be advanced. Today, CERN employs approximately 2800 people, and almost 7000 people, most of them physicists, visit the place for shorter or longer periods every year. Needless to say, such a research facility is expensive to run. Most of the organisation's more than 600 million US$ budget is provided by the member states, based on each country's Net National Income. (CERN's homepage, 2000-01-03)

With European countries facing economic restraints, the demand for some sort of output from the investment increases. The use of the actual results from the research carried out at CERN is at best difficult to demonstrate. Critics even claim that the results are useless from an economic point of view. In order to carry out the research, however, increasingly more complex detectors must be built, and all surrounding technology adapted accordingly. In this development new technologies evolve, and these technologies, in their turn, can be used elsewhere; in industry for instance. Thus, it can be argued that there are possibilities to transfer technological knowledge from CERN to the industry.

Because of the nature of CERN, i.e. in its capacity as an international research facility, there are very strict rules concerning what suppliers to use. In other words, CERN has a very strict set of purchasing procedures. The essence of these is to buy from firms within member countries whenever possible, and to make sure that there is a just rate of return to each member country (*CERN Purchasing Procedures 1998*). Therefore, no firm can be guaranteed to get a certain contract. This also means that a supplier cannot benefit from being successful in the past, because earlier deliveries are not considered in the bidding process. Nevertheless, there are some examples of (successful) co-operation between CERN and different firms. To find these examples, however, it is necessary to get past the aggregated level of the organisation CERN, down to a group- or an individual level.

When it comes to purchasing, CERN's member countries have become more and more aware of the money that is being spent by the organisation. A change in the purchasing procedures that took place in 1994, can be seen as an expression of this concern. In short, this change meant that firms from non-favoured member countries have the chance to lower their tenders in order to get the contract. Therefore, people at CERN have had to become increasingly aware of society's demand for "return on investment". In order to respond to the change in society, attempts to formalise technology transfer from CERN to industry have been made.

[252] Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, the United Kingdom.

These attempts will be discussed further down in the case, but first some examples of interaction between CERN and individual firms are sketched out.

## Transfer in Practise

An example of transfer of knowledge taking place, from CERN to industry, can be seen in the development of the superconducting magnets that are being produced for the new accelerator, the LHC accelerator, that is currently being constructed. This circular accelerator, 27 km in circumference, will need magnets producing such strong magnetic fields that it is only possible to produce it with the help of superconductivity. This, in turn, requires that the magnets are operated at 300°C below room temperature (1.9 K). In addition, the magnets will be more than 14 metres long. All these requirements make it a difficult task to produce magnets that function satisfactorily. As these magnets are crucial for the new accelerator, it is not enough with only one supplier. CERN has chosen to work with three different firms when developing the magnets. At first, there were large problems in getting it right, so in order to be sure that functioning magnets will be produced on time, CERN decided to have its own technical personnel working at the firms' factories, helping them with the production. This made it possible to transfer the technological knowledge needed to produce the magnets. Another question however, is whether this knowledge can be further used by the firms, in the production of other products, because the magnets are quite specific. This also points to another problem with transfer of knowledge from CERN; the specificity of the knowledge. It must also be questioned whether the firms' own personnel learnt anything from the CERN-people, i.e. if there were any remaining signs of their presence in the form of for example changes in equipment. It is of course possible that the CERN-people came and went without really affecting the firms.

Another example of actual interaction taking place between CERN and a firm is in the field of automation systems. ABB Automation Products in Sweden has been working together with a group at CERN during more than ten years, delivering systems for cryogenic control. ABB Automation Products is a world-leading produces of automation systems that are used to steer, supervise, control and protect different types of processes within heavy industry and in power plants. From the perspective of the group at CERN that we are interested in here, the Industrial Automation and Supervision (IAS) group, CERN, or rather the particle accelerator LEP, can be seen as an industrial process producing collisions between particles. This group is responsible for the "production" at CERN – the actual outcome of the particle collisions is the physicists' trouble.

The co-operation started out with ASEA getting a contract in 1985. By 1990, CERN needed additional equipment and ASEA, now merged with BBC into ABB, won that contract as well. This new contract would run over at least five years, until the end of 1996, but it could be extended by CERN to the end of 2000 (which also happened). The difference between this contract and most CERN contracts is that it does not specify exactly what CERN will buy, but it is a kind of frame with a fixed amount of money. CERN specifies via release orders exactly what goods are needed.

Another difference between this relation and most relations between CERN and industry is that CERN takes an active part in the development of ABB's products, by testing them before they are sold on the market. Even though all ABB's automation products are standardised, CERN also has had some influence on the development of specific characteristics. To summarise this brief description: the automation systems are developed by ABB, and CERN does not take an active part in the actual development. An exception from the rule, however, is the requirements from CERN that ABB would install a certain field bus, which, very simplified, can be described as a sort of cable, in their product. In general, however, there is no transfer of knowledge in either direction in this phase. In the testing phase, on the other hand, CERN plays quite an important role, because they know ABB's products well and are able to give valuable feed-back. This can be discussed in terms of knowledge transfer, but there is no traditional one-way technology transfer from CERN to industry. The transfer goes in both directions. Both parties have an interest in the interaction, and it is the rather profound knowledge CERN has about ABB's products that makes the knowledge transfer possible in the first place. ABB is interested in CERN because CERN can provide a perfect testing place (a resource in the form of a facility) before the automation system is ready to be incorporated in a industrial production system. CERN, on their hand, gets a commercial system that is upgraded regularly – and they can influence the development process.

These are just some examples of knowledge exchange between CERN and industry. The interaction between CERN and the firm/firms in question differ between the two examples: in the first example CERN desperately needs a product, and invests quite an amount of both time and resources in obtaining it. In the second example, the product sought is more of a standard product, but the relation developed benefits both parties. Examples like these are, however, desperately sought after at CERN, and there are a lot of activities going on at CERN to try to increase the transfer of knowledge. Due to the increasing demands from the different member countries, there is a large pressure on CERN to, in a way, guarantee the usefulness of the organisation. The changed purchasing procedures is one way to yield to this pressure, another way is to try to formalise the technology transfer.

## Formalisation of Technology Transfer

The CERN Industry and Technology Liaison Office (ITLO) was founded in 1987 to "stimulate interaction with industry and to assist in issues related to CERN's intellectual property" (CERN's homepage 2000-01-03). According to the official document "Technology Transfer at CERN" (FC4126, March 1999), the ITLO's main tasks are: to act as a point of contact for industry in all aspects but direct procurement, to strengthen contacts on industrial matters with CERN Member States' delegates and Industrial Liaison Officers, to promote and assist technology transfer, and to ensure that CERN's intellectual property rights are adequately protected and correctly exploited.

Following the technology transfer document mentioned above, the technology transfer aim was further formalised. A Director of Technology Transfer was appointed, and a whole new infrastructure was constructed around technology transfer from CERN. The Director for technology transfer, Mr. Hoffmann, has the overall responsibility for the technology transfer policy and its execution. He is also one of eight directors in the Directorate, which is CERN's management group. The director is assisted by the ITLO. This office co-ordinates the technology transfer activities, and assists the technology transfer director in dealing with the Finance Committee[253] delegates and industry in the member states. "The office shall initiate, encourage and actively support technology-oriented collaborations between CERN, its partner laboratories and industry, particularly in the member states." Another task laid upon

[253] The Finance Committee is one of the two subsidiary bodies assisting the Council, i.e. the "Parliament" of CERN. The Council bears the ultimate responsibility for all important decisions affecting CERN and its activities. The Finance Committee is composed of representatives from national administrations and deals with all issues related to financial contributions by member states or to CERN's budget and expenditure. Each member state has one representative in the Finance Committee.

the ITLO is to handle the technology transfer database, where firms have the possibility to find contact persons or interesting products/technologies/research. In addition, there are several other people, instances, boards etc. which are in some way responsible for giving advice and enhancing the CERN technology transfer policy.

The document mentioned above, "Technology Transfer at CERN", was first issued in February 1999. It is a way to formalise technology transfer from CERN to industry. The focus of the document, however, is to a large extent on intellectual property rights (IPR), i.e. patents. This means that an emphasis is put on written documents, and more specifically the ownership of, rather than actual transfer of knowledge. The agreements with external partners concerning IPR should be based on two principles. The first principle states that partners first should be sought among firms in member countries, and that the benefits should be spread evenly among these states, in a way that reflects the funding from each member country respectively. The second principle explains that CERN only should enter into a relationship with firms having a good chance of success and a reputation for reliability. Exclusive rights can be granted by the Director-General if non-exclusive transfer may reduce the expected benefits. The Technology Advisory Board is consulted, however, before such a right is granted.

The actual technology transfer is intended to take place through the database, and through topical seminars and workshops. New technologies are meant to be found through technology auditing, and protected via patent applications.

## Transfer of Technological Knowledge from CERN

As explained earlier, few long-lasting relationships are developed between CERN and industrial firms. If repeated interaction is one criterion for transfer of knowledge to take place, then it may be difficult for the companies to learn from interacting with CERN. It can be argued, that if the supplier has similar customers, the experience from one customer can be used in the interaction with others. In many cases, however, CERN as a customer has rather specific demands, which means that the products made for CERN are not likely to be used anywhere else. Other products are purely standardised, and in this case the possibilities for learning are quite low as well. Thus, the combination of completely tailor-made and completely standardised products, and the lack of repeated interaction, do not enhance the possibilities of knowledge transfer. In the examples where knowledge of some sort has been transferred, it is when repeated interaction has taken place in one way or another.

In this case, transfer of knowledge has been discussed on several levels. What is being formalised and what is actually exchanged or transferred is not the same. Likewise, what is being discussed at a central level, done at a central level and done at group level are completely different things. It must also be recognised, that the formalisation of knowledge transfer through the technology transfer function is a political instrument more than anything else. The document that constitute part of the base in formalising the transfer of technological knowledge from CERN quotes the former head of the ITLO, Mr. Barbalat, saying that transfer of knowledge takes place through people, through purchasing, and through collaboration agreements. Thus, although the aim of the technology transfer group is more narrow, in that it to a large extent focus on intellectual property rights, it is still acknowledged that there are several ways to transfer knowledge. There seem to be little discussion at central levels at CERN, however, about what knowledge can be transferred, or even if there are different kinds of technological knowledge.

In the next section, the low-tech case is presented. As in the CERN-case, we focus the description on technological knowledge and transfer issues.

## LOW-TECH: KNOWLEDGE TRANSFER FROM THE AMERICAN CONSTRUCTION INDUSTRY[254]

### Introduction

When the Swedish legal authority Boverket introduced new building regulations, BBR 94, in the turn of year 93/94 it became legal to construct residential buildings of more than two floors using a wooden frame. In earlier regulations wood for framing had been forbidden due to the risk of fire. At this time, the pressure on the construction industry to lower the construction costs for Swedish residential buildings were high due to reduced governmental subsidies combined with an increase in production costs during the preceding years. The technique of using wood for framing was interpreted by some as one possibility to reduce costs, since comparisons between Swedish and American construction techniques, using a concrete frame versus one out of wood, showed that the American way of building is both less costly and less time consuming.

This case is a description of the transfer of knowledge from the American construction industry to Sweden, in order for the Swedes to construct the first Swedish residential building of more than two floors with timber frame built in the twentieth century. The technology described is of a rather simple “every-day” type. This technology is known within the construction industry, but that has not been used in Sweden for the last 100 years. The Swedish building project that is described, Orgelbänken, was started by the large Swedish building firm Skanska together with Linköping´s local housing firm, Stångåstaden, and the architectural firm FFNS Arkitekter i Linköping AB in Linköping in June of 1995. This was one and a half year after the change in regulations. The four floor building consists of 36 apartments with a total building area of 2495 square metres. The project was completed five months later, in November of 1995.

The construction of multi-storey timber houses in Sweden has continued after Orgelbänken and has also spread to the other Nordic countries. Much inspiration and knowledge of how to build multi-storey timber-frame buildings in Sweden has come from the U.S. and Canada, where as much as 90 percent of all residential buildings up til five floors are made using a timber frame. Lately, however, inspiration has also come from other nations, such as Switzerland, where solid timber is used creating higher quality and appeal, but at higher costs. Not to forget, however, is that Sweden has its own long tradition of timber, why knowledge can be drawn from other timber areas, both industrially as well as at research institutions.

## Technological Knowledge within the American Construction Industry

The interest in the American homebuilders started in 1992 when the Swedish Federation for Rental Property Owners observed that the costs of home production were remarkably low in

[254] The material used for this case is part of a larger material collected in a study of technological development in the construction industry. In the larger study, the reintroduction of multi-storey timber-frame buildings in Sweden is discussed in relation to different influences and hinders. A comparative study is also conducted on Nordic level containing empirical material from all the Nordic countries ( except Iceland).

the U.S. compared to Sweden.[255] To find out more about the American homebuilders and their way of working a study was conducted. The study concerned multifamily housing and incorporated the following areas; a detailed comparison of the production costs, product description of Swedish and American residential buildings, service and maintenance and a market analysis for a residential building project in the U.S.

Two representatives from the Swedish homebuilding sector, Tom Miller, director of research and development at the Swedish Federation for Rental Property Owners, and Gunnar Stone at Skanska, travelled to Washington and Minneapolis[256]. In order to make the comparison of differences in building methods and costs in the two countries a co-operation was established with American HAD, Department of Housing and Development. Based on the results a book "Multifamily Housing in the USA and Sweden – A Comparative Study" was written. Other studies were also conducted, at Lunds Technical University in Sweden and by the Swedish Attaché of Technology in Los Angeles.

Knowing in advance that the American costs were lower than the corresponding Swedish ones, they were still amazed by the difference in both costs and time spent on a building project; "The difference in production time, was after the difference in costs, the most astonishing difference between Swedish and American housing. The typical American residential building takes about half as long time to build as a corresponding Swedish."(Rapport P9504018, Trätek, Per-Erik Eriksson) The difference in costs was larger than expected; to build a square metre apartment showed to be less than half as expensive as in Sweden; sometimes the costs were as low as one third of those in Sweden.

In order to find out if, and then to what extent, the difference in time and costs spent could be explained by differences in standards and quality of housing in the two countries, one of the studies describe in detail a typical American multifamily building located in Kentucky.[257] The description contain information on the housing estate, planning of apartments and standard of equipment. The building technique that had been used is also described briefly. The gist of the report is that American apartments have the same standard as the Swedish in most aspects, in some respects the American median apartment had even higher standards. On the other hand, the building technique, the surface materials and some interior components were much simpler than the Swedish ones. The demands from authorities in the two countries were also compared and documented in the reports to see if cost differences could be explained by these. Demands of fire protection were found to be almost the same, whereas the regulation for sound protection were lower in the U.S. The latter was, however, exceeded in most American projects due to demand from the tenants.

The studies showed that the building techniques used in the two countries was one of the biggest differences between American and Swedish housing production, and that the largest single difference within this category was the framing. As much as 90% of the American residential buildings are built with a timber-frame, the same technique as was used for single homes in Sweden. This type of framing will, as described in the reports, result in a light frame with simple foundation, quick production and low costs for the frame as such.

[255] The idea of comparing housing in Sweden and the U.S. is however not a new one, as explained in the book by Miller and Stone. They describe a long tradition of cross-fertilisation, starting with the first American houses of horizontal planks that are said to have been influenced by Swedish and Finnish immigrants.

[256] The climate in Minneapolis and Sweden are rather similar, so differences in production costs can not be explained by this factor.

[257] Utlandsrapport, USA 9304, Sveriges Tekniska Attachéer

Estimations made showed that the savings compared to a building with frame made of concrete are 20-30 percent of the cost of production. To acquire more knowledge about the timber-frame technique a complete report is dedicated to this subject. Main focus in the report is on the design of the frame of joists with respect to fire protection, minimising the spread of sound and vertical shrinking. These are the three areas that are considered to be main problems in relation to a timber-frame.

## The First Swedish Multi-storey Timber-frame Building

The results of the study comparing multifamily housing in Sweden and the U.S. did of course make it interesting for the involved parties to test the American building technology under Swedish conditions. Skanska therefore approached Linköping´s local housing firm, Stångåstaden, in 1994 with a suggestion to develop a four storey residential building project that had been laid on hold, using the American site building technique with a timber frame. With the newly acquired knowledge of the American production technology they planned to build the house of approximately 30 apartments within eight months.

A study tour to Minneapolis was made in December of 1994 by the people directly involved in the project together with Stone from Skanska. The tour was arranged in order to establish further contacts with American project engineers, builders and owners, to grasp some of their knowledge of multi-storey timber frame houses. On this occasion several actors were visited, and a number of building projects in different phases of production were studied on site. The production was also video-taped and analysed in Sweden. This analysis was made in several steps: Initially, the tapes were watched and discussed in the production planning phase, and later on, the techniques were introduced to the timber-men. These observations together with the previous studies were an important base for the project planning. During this period the demand for further knowledge and the difficulties of the task were much clearer. An additional five months had to be put on technical studies of sound at Lunds Technical University; fire at Trätek in Stockholm; and installations. Among other changes a re-disposition was made in order to minimise disturbing noise and make the installations more efficient. In total 42 project meetings were held during the period of May 1994 until May 1996 (the last meeting was a follow up).[258]

Since the original construction agreement between Skanska and the housing firm Stångåstaden concerned a concrete building of 28 apartments that should have been built in 48 weeks, rather large changes had to be planned for and handled in the project. The final building has a timber-frame. It consists of 36 apartments and was produced in 34 weeks. At the most 15 timber men were occupied with the production of Orgelbänken. Compared to common building projects in Sweden, more responsibility for planning, exposure and realisation was given to the workers and the staff at the project site was reduced to a minimum of just one person in charge of production. Stone argues that this organisation was one important reason for the high productivity per worker that was accomplished at Orgelbänken; “Timber men are well educated in Sweden, but that knowledge is usually not utilised. In an ordinary concrete building project timber men only get to nail concrete moulds. Of course there were happy tones!”

[258] This is more than double the amount of project meetings that is usually held.

## Transfer of Knowledge from the U.S. to Sweden

”If one tells the American builder that nothing above two floors is built with a timber-frame in Sweden, he will say; “But you have wood in Sweden, don’t you?” If one then answers that products made out of wood make up our largest share of exports, but that we are not allowed to build in wood after the city-fire of Sundsvall in 1888, he will roll up his eyes to heaven. Through out the years the American homebuilder has become convinced that this is the only way to build. Just like the Swedish homebuilder is convinced that cast-in-situ concrete is the only thinkable method.” *(Utlandsrapport, USA 9305, Sveriges Tekniska Attachéer, author’s translation)*

Orgelbänken was planned to be built using the knowledge of the American site building technique for home production. This knowledge was meant to be transferred from the U.S. Once in Sweden, however, the constructors were during the process forced to discover that “as close to the original as possible” was very far from the original in this project. With some disappointment, Stone admits; “We did not pull through on almost anything American.”

One reason was the difference in prescriptions from building authorities in the two countries. Even though the frame is protected from fire using the same method, i.e. covering the frame with gypsum board, and the demand for fire resistance is almost identical, the Swedish authorities demanded almost the double amount of gypsum for fire protection. In one of the reports the authors write in resignation; “The conclusion of this must be either that the Swedish gypsum boards are of remarkably lower quality than the American, or that the American constructions are less safe (something that the author show statistical evidence against; own remark), or that our methods and criteria are unnecessarily conservative.”

Perhaps more important, however, was the fact that the industrial network around Skanska has evolved around the concrete building technique. Some of the products used in the American buildings were difficult, or impossible, to find not only among Skanskas regular suppliers but in Sweden. An American board, the OSB-board, was even imported directly at very high expenses to the Orgelbänken-project. As a reaction to this, Swedish board producers have conducted tests at Trätek’s fire laboratory in order to prove that the Swedish alternatives work just as well for the purpose (closer co-operation has also been established between Swedish board-producers and Skanska after this first project). In general no “timbre-frame adapted” products were available on the Swedish market. They had to be tailored for the project, something that claimed both time and resources. Similar problems were also faced by the architect and the constructing firm, who naturally, had few if any previous experiences with this particular framing-technique and its consequences on their work.

The single largest problem in the project and for the continuance of the development may, however, be the lack of prescriptions. All the involved actors in a building project have a pre-understanding of the task ahead. In Sweden these pre-understandings are based on concrete-building-projects, whereas a timber-frame-project is dealt with as an exception. Measurements etc. are made on the premises of concrete: Architects and constructing engineers had neither the knowledge nor the equipment to make drawings and calculations on the premises of timber. Consultants and installation engineers did also raise their prices with 10-20% since they could not make proper calculations of what their costs would actually ad up to.

## INTERACTION AS A MEAN TO ACQUIRE KNOWLEDGE

The two cases that have been presented represent very different areas of technology. The first case discusses the European Laboratory for Particle Physics, i.e. CERN, and the attempts that have been made there during recent years to enlarge the return to the member nations by formalising procedures and applying for patents. In the second case, the technology is of a more mature type, known by many and used by more than a few (all the homebuilders in the U.S. and Canada among others). Nevertheless, there are some striking similarities between the two cases as well. In both cases the description is concentrated around a struggle to transfer technological knowledge from one organisation (CERN) or nation (the U.S.) to another nation or nations. Both cases therefor illustrate some of the difficulties involved in the process of transferring technological knowledge.

In this final part of the paper we will, based on the two cases presented, discuss some of the aspects involved in the process of technological knowledge transfer. As shown in the cases, firms do not function in a vacuum. Rather, they exist in a context, and this context is important for the way firms work. Firms act in this context, or environment. They buy and sell different things, and thus interact with other firms. In many cases, firms can be said to have long-lasting relations with other firms, or other actors. To be able to do things, i.e. perform activities, resources are needed. Therefore, firms control resources, and these resources can be combined in different ways; both within and between firms (see e.g. Håkansson 1987, Håkansson 1989, Waluszewski 1990, Lundgren 1995).

As described earlier in the paper, knowledge can be defined and dealt with in several ways. Using the cases as a point of departure, however, we have seen that it can be fruitful to make a connection between the concept of knowledge and that of resources, as used in the industrial network theory (see e.g. Håkansson & Snehota, 1995). A resource is there described as an element, material or immaterial, that has some known use. The value of the resource lies in the use potential and is thus never fully known, i.e. it can always be evaluated further. Or, as Håkansson and Snehota put it: "Whether an element is to be considered a resource, depends on the known use for it. Various elements, tangible and intangible, material and symbolic, can be considered a resource when use can be made of them. No element without known use is a resource and the value of resources lies, of course, in their use potential" (1995:132). Perhaps the attempts at CERN to find patentable innovations can be viewed as efforts to show the value and thereby usefulness of their work.

The combination of resources require knowledge. Håkansson and Snehota (1995) state that "When different companies activities are carried out and resources are used, some kind of knowledge of how they can be combined is needed. This knowledge of resources is only partly explicit, which means that it can be articulated, codified in the form of documents or books, and thus is relatively easy to transfer. Perhaps the main part of the knowledge necessary in order to use resources and to undertake activities is more difficult to articulate. It is "tacit" in nature" (p. 14). It is also evident from this line of reasoning that much of the knowledge used in a firm is not indigenous to the firm, but becomes available through its relations with other firms. Thus, the relevant knowledge is spread among different actors, and not all of it can be accessed. "The know-how of a company and its competence is dependent on its relationships that are thus an important tool in connecting the knowledge of various actors" (Håkansson & Snehota, 1995:14). Håkansson and Snehota also claim that "[i]t is in relationships that the existing knowledge is confronted with other parties' knowledge and new knowledge is created" (ibid.). The low-tech case implies that much of the relevant concrete-related knowledge is spread among the actors in a way that makes it difficult to know what ”new” knowledge that needs to be transferred from the U.S. in order to use the technique in Sweden.

As already mentioned, the combination of resources can be made in an enormous number of ways. The resources in themselves, however, are highly heterogeneous, and how to combine them is therefore not an obvious task. Alchian and Demsetz (1972) argue that the result of a combination of heterogeneous resources is impossible to know in advance and therefore has to be learned. The combinations have to be tried out in what they call “teamwork”. Even if firms can learn from single business transactions, time and repetition enhance the possibilities for acquiring knowledge (Håkansson & Snehota, 1995:140). Through continuous interaction with resource providers, a firm can learn more about the use of resources. But in order to have time for this to happen, a certain stability is needed. Therefore, continuity in relationships increase firms’ possibilities to acquire knowledge. Seldom is all knowledge about resource combining transferred, however, because firstly, much of the knowledge of resources is tacit, and secondly the counterparts continuously develop their knowledge in their relations with other actors (ibid.). In both cases, knowledge is transferred, or meant to be transferred, from one network to another. There is thus no knowledge development or knowledge transfer through repeated interaction. Another similarity is that knowledge in both cases is treated like an item that can be lifted from its context, i.e. decontextualised, transferred as a “package” and then incorporated in another setting, i.e. recontextualised (se figure 1).

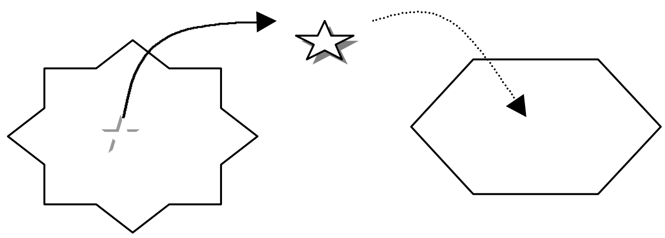

***Figure 1***: Decontextualisation and recontextualisation of knowledge

## The Translation of Knowledge

What knowledge is transferred then, and, equally important, what knowledge is integrated? There is a whole school of thought concerning the diffusion of ideas and different kinds of models (see e.g. Czarniawska & Sevon 1996, Røvik 1998). It can easily be shown that ideas do travel, that is, they spread from one organisation to another, within countries and across borders. But what is it that travel, i.e. what is diffused? And what is implemented, or, in other words, translated? Røvik (1998) discusses the translation of management ideas.

Røvik bases his translation theory on Latour’s (1986) model of translation. The essence of the translation model is the fact that everything – claims, orders, artefacts, goods etc. – is spread by people, and that people act in different ways while spreading the item, thus translating it into something new. The translation model is, however, developed by Røvik to include such issues as why recipes usually are translated and where the translations are carried out.

According to Røvik, many translations are an expression for attempts to avoid conflict situations. Not all ideas fit within all organisations, and a translation of an idea is a way to adapt it to specific circumstances. It is also impossible to copy a model one hundred per cent.

Attempts to copy a recipe therefore almost without exclusion ends in some sort of translation – intended or not. Some of the reasons for this are limited time and capacity, and the distance between the ideal organisation and the one trying to adopt the idea or model in question. Translation can also take place as an attempt to manage the identity of the organisation. Caught between on the one hand the will to be unique, and, on the other hand, the urge to resemble the others, a gentle translation of models and ideas can be one way to cope. The point made by Røvik, and the one that we use here, is that the translations are not always negative or that they only "take away" elements from the technology adopted, but just that translations do happen. The consequences of translations is another, or further, issue, not dealt with here.

What becomes obvious in the two cases is that transfer of technological knowledge, even between similar firms within the same country, is more difficult than it may seem at first sight. In reality, it is nearly impossible to transfer knowledge without it being changed in some way. As soon as knowledge travel, some sort of translation takes place. This holds true for the timber-frame case, where the Swedish building project Orgelbänken ends up far from its American model. Why did this translation take place then? Part of it was of course intended translations, made in order to avoid conflict situations. We would however allege that the largest intended translations from the origin in the U.S. were made in relation to other firms involved in the project, rather than due to internal conflicts in any of the involved organisations.

We would also like to claim that the unintended translations had more to do with distance between local industrial structures, or networks, in the two countries, than with distance between for example an American homebuilder and the focal building firm in Sweden, Skanska, in isolation. How successful a single organisation such as Skanska is in transferring the American production technology has to do with other parties; the abilities and willingness of the architectural firm and the constructing engineer, whether the materials and components used in the U.S. can be produced by Skanska's suppliers and if so at what costs, and if they can not; what the cost of going outside the established relationships in order to buy the products would be, etc. There is a whole network of other firms with resource possessions related to a single actor that affect, and will be affected by, the transfer of technology. This is also the reason why the result of the transfer as shown in the building project Orgelbänken was only partly an imitation, where just a few elements were adopted.

Technological knowledge that is transferred from CERN to a firm is also translated. One of the reasons for this is that the knowledge has to fit into an entirely new context. That is also a problem with the inventions that CERN tries to patent. Through the formalised technology transfer system, the aim is to find inventions that could prove important for industry, to apply for patents and then transfer these patents to industry. What is completely forgotten is that these inventions were not made at the same place as they are intended to function, and it is absolutely not certain that the product will be of use in another network. We do not claim that ideas can not be transferred from one place to another. The technological knowledge will not be transferred as a whole, but rather translated and changed in many ways. For instance, a solution to a technical problem may be transferred, but not the methods or ways to reach that solution.

In order to study transfer of knowledge, and the problems with the transfer, it is not enough to study why and where the transfer takes place. The context must also be considered. We have already stated that we see technological knowledge as context specific. What happens then, when attempts are made to transfer this knowledge? Can it be transferred, is it translated into partly something new or is it impossible to transfer at all? In the next section we discuss context in terms of embeddedness.

## Resource Embeddedness and Knowledge Translation

As shown in the cases, firms do not function in isolation. According to Granovetter, “Actors do not behave or decide as atoms outside a social context” (1992:32). In our words, this means that firms interact continually with the same firms, in long-lasting relations. This interaction leads to firms adapting to each other, thus making context-specific adaptations. Granovetter (1992) discusses the concept “embeddedness”, by this meaning “that economic action and outcomes, like all social action and outcomes, are affected by actors’ dyadic (pairwise) relations *and* by the structure of the overall network of relations” (1992:33).

In the same way as relations can be seen as embedded in a network of relations, so can resources be discussed in terms of embeddedness. Before we discuss the concept of resource embeddedness however, we will start by recapitulating some of the characteristics of resources. As mentioned earlier, an element is only a resource when there is some known use for it (Håkansson & Snehota). There is potentially an unlimited number of ways to use an resource in combination with other resources. Resources are thus heterogeneous, and the heterogeneity in a resource means that the knowledge of its characteristics, or features, is never complete in all respects (Waluszewski, 1990) and will differ between actors. Even if there is an unlimited number of ways to combine resources, most resources in a firm are however already tied up in resource constellations (Waluszewski 1990, Håkansson & Snehota 1995): The resources are embedded in a structure. The more ties to other resources a certain resource has, and the more of its features that are used in the specific context, the more embedded it can be said to be.

Technological knowledge can, following our line of reasoning, be defined as the built in, individual and/or collective knowledge of how resources can be combined in order to create economic value. As the combination of resources, from our perspective, is context specific, this definition of technological knowledge implies that knowledge in itself is context specific. The technological knowledge is developed at the place where the resources are combined, in the specific context. Despite this, there seems to be an overwhelming belief in the possibilities to transfer knowledge by simply transferring documents. The embeddedness of resources is seldom taken into account. Attempts at CERN to formalise the transfer of technological knowledge is only one example. If it is true, and we believe it is, that knowledge is developed over time in relationships, then formalisation of knowledge is problematic. In order to formalise something, it has first to be decided what is important and what is not. Considering that the use of knowledge will differ from place to place in relation to existing resources, the decision whether certain technological knowledge is important or not is impossible to make before the process of transfer.

Knowledge is here seen as a resource dimension, rather than an item or a resource in itself. If then, and we claim it is, the value of resources differ depending on how they are combined, each set of resource combination within a certain industrial network is unique to some degree. An result of this uniqueness of the situation or context is that all optimisations are made in relation to something specific, rather than in general. There is a degree of subjectivity in all technological knowledge, and the subjectivity is favouring the existing context, i.e. given a certain context this use of the resource is the best we know.

Given that the technological knowledge is context specific, i.e. developed in relation to resources that are embedded in a certain network, the existing network on the adopting side play a major role for the technical and economical results of the technological knowledge transfer, as well as for the possibilities to accomplish any transfer at all. Can the new knowledge be combined with the resources in the existing structure? What are the costs of adaptation, in new facilities, new or changes components as well as in over-capacity in old facilities etc., and for whom is it a cost? The abilities and willingness of the involved actors play another major role in order to understand the process of transfer. Who has acquired new knowledge? Who else needs to develop new skills in order for the development process to work? Will they be interested in doing so, i.e. what is in it for them?

Drawing upon the discussion about resource embeddedness and context specific knowledge, we believe that the resource embeddedness can affect the transfer of technological knowledge in at least three different ways. Firstly, the more ties that exist between the resources in a network, the more complex it becomes to change a single resource. Adaptations have to be made in many of the resources and in the combinations of these in several steps, i.e. the embeddedness of resources will complicate the transfer. Secondly, however, the same embeddedness result in mutual or overlapping knowledge of resources for several actors. The fact that actors, and their existing knowledge about the resources and how they function in certain combinations, are not isolated from each other will ease the transfer. Thirdly, if two companies are embedded in similar resource constellations, then the transfer of technological knowledge, for example a solution to a specific technical problem, is much easier to carry out. In this case the similarities facilitate understanding between place of origin and the adopting firm.

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