Construction Companies and How They Acquire Knowledge through Business Interaction

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Abstract
By combining the two phenomena 'knowledge' and 'interaction', in terms of how they can vary in both intensity and content, this article attempts to deepen the understanding of the relationship between different types of interaction and learning, and, more specifically, how it appears within the construction industry. As an industry, construction displays some specific features in relation to interactional patterns that seem to hinder the establishment of more extensive long-term interactions. Through distinguishing between different types of interactions we discuss potential learning opportunities. The theoretical discussion is exemplified with empirical material from the construction industry that we glean from both earlier studies and from an ongoing investigation of Swedish construction firms. Our results indicate that there are different degrees of knowledge being transferred in the construction network, and that there are examples of close interaction where joint learning takes place. However, the organisational conditions characterising the construction industry seem to provide little incentive to invest in long-term relationships, thus affecting what can be learned from others. This research project has been financial supported by the Swedish Construction Federation and The Jan Wallander and Tom Hedelius Foundation.

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Introduction

Knowledge is and has always been important for companies. In 1890 Marshall stated, "Knowledge is our most powerful engine of production" (Marshall 1965 p. 115, orig. publ. 1890). This was echoed by Castells (1996 p. 218), saying "The source of productivity and growth lies in the generation of knowledge". Today it is popular to discuss and analyse the 'knowledge economy' as well as the 'knowledge based company' (Nonaka 1991; Grant 1996; Dunning 2002), but as the quote from Marshall indicates, knowledge has always been important for producing companies.

This also means that knowledge is and has been important for construction companies (Robinson et al. 2005). There it is important both in terms of knowledge about the building object and its function (houses, commercial buildings, roads, dams, etc.) as well as of the construction process. Over the years the increased use of more advanced technologies, both in the objects as well as in the construction process, increases this need (Laborde & Sanvido 1994). Examples are the use of more advanced machines and equipment, IT tools for construction and planning (virtual construction), the increased use of technical platforms and 'intelligent' or energy saving buildings. The use of existing knowledge and renewal of this knowledge, including developing innovations, is certainly crucial for the modern construction company.

Interaction and the development of business relationships have been major conclusions in different business studies for a long time (for an overview see Håkansson et al. 2009). Interaction and business relationships are argued to be of significant importance for the knowledge development of any company related to marketing, purchasing, technical development and strategy (ibid). It has even been argued that interaction may create joint knowledge (Håkansson 1993). Furthermore, the empirical studies of business relationships also demonstrate that there is a large variation in how companies in general interact with each other. Studies of construction companies give the same picture. Interaction is of central importance even if the construction companies show some special features (Håkansson et al. 1999; Dubois & Gadde 2002; Bygballe et al. 2010). Construction is a project based business, which means that the companies manage their activities mainly through individual projects (Bygballe et al. 2010). The high occurrence of public procurement and a strong tradition of tender procedures further concentrate the industries' operations to single projects (Green &

McDermott 1996; Gadde & Dubois 2010). In the projects there are often new counterparts and solutions to which the single construction company must relate, which then requires problem solving and coordination of various activities and resources. However, as suggested by Dubois and Gadde (2002), this interaction only result in temporary relationships, confined to the duration of the project, and is not transmitted to the permanent network in the shape of long-term relationships. Thus, the project based way in which construction companies are organised makes it more difficult to establish continuous and long-term relationships and there is also an established way of prioritising short-term transactions within the industry. As has earlier been suggested (see e.g. Gadde & Dubois 2010) and which will be further discussed in this paper, this may not present suitable conditions for learning and knowledge development. Also, the issue of finding solutions to the problems connected to the fragmentation and one-off nature of construction operations has occupied both governmental and industry actors for the last fifty years (Bresnen & Marshall 2000). It is believed that there are both cost and learning benefits to be gained from more long-term interaction within the construction network (Esterby-Smith et al. 2008; Gadde & Dubois 2010).

In this paper we want to explore in more detail how interaction and knowledge development can be combined in general, and especially apply it to construction companies. A problem, but also maybe an interesting possibility, is that both of these phenomena are multidimensional. As was described above we have found that interaction can vary in several aspects. The intensity can vary and so can the content. In the same way 'knowledge' is a multidimensional phenomenon. Thus, when we combine these two we get a number of ways to combine two quite varied phenomena. A wide variety in interaction can lead to a wide variety of knowledge development. This article is a modest attempt to give a first picture of this variety. A second ambition is to analyse the special problem that construction companies have as, according to the discussion above, they have difficulties in developing more long-term interaction. Thus, there are special reasons to investigate how interaction and knowledge exchange can be combined in the construction sector.

The companies may interact in some very different ways and this variety should influence their knowledge development. Consequently, different types of restrictions in the interaction should have consequences for knowledge development. We want to understand how these restrictions in interaction can influence knowledge development, especially for the possibilities of developing joint knowledge in construction companies.

Interaction and knowledge

In earlier empirical studies of business networks we found some very direct connections between interaction and knowledge (Håkansson et al. 2009; Håkansson & Johanson 2001). The three most typical situations, where we probably have hundreds of empirical examples for each, are as follows:

1. Interaction as a way to learn – to gain knowledge. Interactive relationships are, in many situations, an important means to exploit the knowledge of others (Snehota 1990; Bygballe 2005).
2. Interaction as a way to teach – to actively transfer one's own knowledge. Interactive relationships are, in many situations, an important means to influence others in a systematic way (Gadde & Håkansson 2007; Håkansson et al. 2001).
3. Interaction as a way to combine knowledge – to actively confront the knowledge of one actor with the knowledge of another. Interactive relationships as a means to 'create' new knowledge. Many new innovations have their source in business relationships (Von Hippel 1988; Håkansson 1993; Van de Ven et al. 1999).

The two first examples deal with how interaction functions as a way to transfer knowledge – to move it between different actors. We have a large number of cases where knowledge has been moved from a producer to a customer or from a customer to a producer (Håkansson ed. 1982; Håkansson & Snehota 1995; Håkansson & Waluszewski 2002). The moving of knowledge can be done just by moving a product that has a specific knowledge content, but it can also be done by adding knowledge as a special service to the product. In simple cases it can be in terms of a manual but in more difficult situations there might be need for extensive training of many people. To learn and to teach is somewhat difficult and given the type and amount of knowledge, more or less interaction is needed. Some knowledge transfer requires more training and instructions and, consequently, the involvement of more people on both sides. Still, interaction seems to be the key mechanism to handling such problems.

But as the third point suggests, interaction can do more. There are reasons to also assume that interaction is one of the ways new knowledge can be created (Håkansson 1993; Vercauteren 2006; Hoholm 2009). There are several reasons why this can happen. One is that interaction as a process can be creative and problem solving. Therefore, one possible outcome of interaction should be innovations. Another reason is that interaction between companies is a boundary activity. Interaction connects two different knowledge bodies –it takes place at the boundaries (or between them). New knowledge is often said to appear in the boundary area between different knowledge bodies, when knowledge from two areas is combined. If this is the case, then interaction could be an important means of creating innovations or new knowledge. But then interaction must have some special features – it must have a special content. It requires that interaction includes some kind of a problem solving process where the two parties actively try to confront what they know. To develop new knowledge there must be an activity where the existing knowledge is tried out and found to be inappropriate.

Thus, for interaction to be a source of new knowledge we need a special interaction. Or we can formulate in more general terms by stating that the features of interaction determine what kind of knowledge can be transferred and created. In the construction case it has been argued that

there are some specific limitations on the interaction and this ought to affect the potential for knowledge development as well as transfer. To investigate this aspect we have to start out from some more generalised descriptions of interaction and knowledge.

Interaction – from pure exchange to networking

The discussion above revealed that in order to transfer or create knowledge we need interaction of a certain quality, or with some specific features. Thus, we need some way to categorise and identify differences in the interaction and in the knowledge. For interaction we will suggest a classification building on a categorisation developed by Cantillon (2010) based on Håkansson and Prenkert (2004). The latter identified four different types of exchange systems, each based on a specific type of exchange related to both different theories and empirical examples. Cantillon (2010)

Håkansson & Prenkert (2004)	*Cantillon (2010)*	*Used here*
	Pure exchange	Pure exchange
	Light co-operation	Minor social exchange
Buying/Selling Activity System	Buying/Selling	Technical exchange
Producing/Using Activity System	Producing/Using	Technical exchange
Co-operation Activity System	Close co-operation	Co-operation
Networking Activity System	Networking	Networking

Figure 1: Three classification systems for interaction

	Products	**Facilities**	**Business units**	**Business relationships**
Pure exchange	No change	No change	No change	None
Light cooperation	No change	No change	Minor change	Single
Buying & selling	Change	No change	Minor change	Single
Producing & using	No change	Change	Minor change	Single
Close cooperation	Change	Change	Change	Single
Networking	Change	Change	Change	Several

Figure 2: Interaction and change in resources (Source Cantillon 2010 p. 52)

wanted a classification scheme to characterise different ongoing interactions in an empirical field and she used these categories as a base to identify four types of interaction that she then complemented with two more types. In Figure 1 the two earlier developed categorisations and the one suggested here are presented.

The classification developed by Cantillon (2010) was used to investigate the changes in the resources created by different types of interactions. From an empirical point of view it was the changes in the resources that could be identified and that was used as an indirect way of measuring interaction. Table 2 was used by Cantillon 2010 to describe what is changed in relation to types of interaction. This is also an indirect way of identifying what kind of knowledge is exchanged in the interaction.

As can be seen in Figure 2, the third and the fourth categories both deal with technical features related either to the product or the facilities. These two categories identifying different effects on technical resources (products and/or facilities) will be brought together under the label 'technical exchange' (see Figure 1). There is one main reason. From a knowledge point of view they are very similar; the knowledge is limited to some specific technical features in products or facilities. They are also similar in that this type of interaction does not assume any larger 'social exchange'. Thus there is no need for the development of long lasting business relationships. This type of technical exchange is mainly one-sided, i.e. that those involved can adapt to the others without requiring that the others also should adapt. Learning is taking place through a one-directed process – from the environment into the company.

Let us now, in more detail, go through the five identified categories that will be used here and how they can be characterised by building on the description given by Cantillon 2010, p 51.

- Pure exchange – in this case there is no relationship; it is a short time horizon; products or services are exchanged for money and resources remain unchanged by the interaction. There is no knowledge transferred except the one existing in the product. This is the type of exchange that is assumed in the perfect market model.
- Minor social exchange (labelled light co-operation by Cantillon (2010)) – interaction close to pure exchange but with some social sentiments developing through repetitive exchanges, short time horizon; narrow resource focus; interaction that results in minor changes in the orientation and/or knowledge of the involved actors but only regarding the counterpart's existence and features.
- Technical exchange (buying & selling and producing & using in Cantillon (2010)) – single relationship; short or long time horizon; narrow resource focus on the technical features; interaction that results in changes being made to the product and/or the production facilities; mainly one-sided effects; minor change in the business unit. Specific technical knowledge can be transferred.
- Co-operation – single relationship; long term; wide reaching (both sides affected); interaction that results in changes being made to multiple tangible and intangible resources. Often extensive knowledge content in the interaction.
- Networking – several relationships involved; long term; wide reaching (more than two parties affected); interaction that results in changes being made to several tangible and intangible resources in the dyad; deliberate changes being made to resources in third party relationships; several parallel knowledge processes appear in the interaction.

The five categories form a Guttman scale – interaction belonging to a 'higher' category may include sub-processes belonging to the lower categories. It means that in situations including networking there might also be interactions of all the other types. In pure exchange there is no knowledge transferred that is outside the 'product'. The second category covers cases where the interaction is more or less 'planned' to be pure exchange but where the involved parties, through the exchange, get to know each other. Thus, there are some personal sentiments exchanged that affect what the involved parties know and feel about each other. This might affect the choice of counterpart in coming interactions. In this type of interaction the parties learn about each other and the way the other interacts.

In the technical exchange situation there is some specific knowledge exchanged regarding technical features. There might be some specific adaptations to the counterpart. One or both sides can adapt its technical solution to the counterpart – but each change is always done one-sided. There is no joint problem solving. That would require a broader and more frequent social interaction. Special application knowledge is one typical example of knowledge development.

The two last categories include all situations where both parties are directly active in the knowledge exchange with the counterpart. In the co-operation category both parties are trying to both teach and learn, to both influence and be influenced. They are trying together to solve some problems where the counterpart must be included. It can be joint problems or individual problems but the counterpart has to be involved in order to find a solution.

In the networking case there is the need to involve at least one third party in order to solve the problem. It means that the knowledge exchange can be in three different dyads or jointly including all three. In this situation the total knowledge process will generally be related to more interfaces as it includes more parties, products and knowledge bodies.

Knowledge – from knowing who to knowing why

The way knowledge is defined and treated is at the heart of the general philosophical discussion. In the postmodern version one important aspect is that knowledge is relative. It is not objective or neutral; instead it is dependent on how it has been produced. It is a construction and every part (or element) is dependent on other parts (or elements) (Galison

1997; Bijker 1997). It also means that any piece of knowledge, new or established, is always related to the context in which it has been produced and thus to the established knowledge, culture, institutions and technologies in that particular setting (e.g. Shapin & Schaffer 1985; Latour 1987; Mol & Law 1994). As such, knowledge is the result of a specific and context dependent process through which it was either intended to solve particular problems or developed more or less unknowingly through the carrying out of new or routine activities. This means that there are different ways in which knowledge comes about, how it is used and consequently also several ways in which it can be characterised. One popular way to identify different aspects of knowledge is to distinguish between know-what (facts), know-how (tacit), know-why (science) and know-who (networking). This classification suggests that there are several aspects that are important in relation to knowledge, i.e. that knowledge is a rather complicated and tricky phenomenon. It includes facts and how to use them. It includes explanations but also who has these explanations. Knowledge is partly something that we can separate from ourselves and formulate in explicit terms but it also includes aspects embedded into single people or organisations. This stands in apparent contrast to the neoclassical interpretation of knowledge in which economic actors are assumed to be able to make rational decisions (from an objective standpoint) provided that they have access to all available information (O'Sullivan 2004). In turn this makes the use of knowledge (and thus learning) simply a matter of gaining access to it. If the assumption instead is that knowledge is heterogeneous, and thus a context dependent phenomenon, the use of knowledge becomes as intricate as its production. Or, as put by Ståhl and Waluszewski (2007, p. 142),: "To use knowledge is also to produce it: to learn." This has consequences for how we must understand how people as well as organisations produce and make use of knowledge, or how they learn. Drawing on the work by Lave and Wenger (e.g. 1990), Ståhl and Waluszewski, (2007) describe learning as a process anchored in the social and physical structure in which it takes place, that learning is 'situated'. Thus, learning is a dynamic process through which knowledge is activated by being combined with the existing knowledge, culture, practices and devices in any particular context. Accordingly, learning in a company can be done in three different ways. A company can learn through its own experimentation (learning by doing), it can also learn from others as described above. Finally, there can be joint learning when several actors (companies) combine and experiment to solve problems (Håkansson 1993).

How knowledge is used and activated is especially of interest from an economic point of view – knowledge gets its economic value out of use. Knowledge thus has an 'economic dimension' (Håkansson & Waluszewski 2004) dependent on the particular context and that is not revealed until the knowledge becomes part of the organisational and physical structure of that context. How a body of knowledge is used in one context, and the economic effects that are created as a result, might thus be vastly different from those created by the same knowledge's activation in another setting. A rather straightforward example can be posed by knowledge that is activated as science within academia and as commercial production of new products and services within business. New scientific knowledge is, within an academic context, used mainly to produce publications, engage and educate new researchers, and form new research projects. It is activated by becoming embedded in the established stock of scientific knowledge through which it acquires certain meanings and is suited for certain purposes. Here the economic effects are more indirect in terms of researchers acquiring funding, people getting educated, and knowledge over time slowly leaking out to be applied in various industrial applications. Within a setting where the same new knowledge is to be used for the direct purpose of creating commercial products and services, it is instead activated by being combined with established products and production processes as well as supplier and customer relationships. Here the economic effects are directly determined by the knowledge's compatibility with this established structure, the resulting use of the products or services within the customer setting as well as its compatibility with earlier supplier investments. In this case, as it is new science and therefore not related to any established investments within business, such activation will most likely be a difficult and costly process (Håkansson & Waluszewski eds. 2007; Ingemansson 2010). As knowledge needs to be activated in order to create any economic effects, it also needs to be made compatible with the already activated structures in any particular context. This creates problems if there is no or little relatedness between the supplying and implementing contexts (Håkansson & Waluszewski eds. 2007).

Another problem that has been discussed and that is related to some of the features discussed above is that some knowledge is 'sticky' – it is not easy to move (Von Hippel 1998). This aspect directly affects the need for interaction if it is to be moved. When the stickiness increases it requires a more extensive and high quality type of interaction to manage transferring the knowledge. Thus, knowledge that is not explicit and/or formalised but embedded into people, routines, and organisations requires more interaction if it is to be moved or to be actively used by others. In conclusion, knowledge has features that make it more or less easy to transfer. Furthermore it can also emerge out of interaction. Collective or joint knowledge requires active interaction and the same is the case for transferring sticky information.

Combining interaction and knowledge

We can now combine the interaction and knowledge dimensions with each other and look at what kind of knowledge is involved in the different types of interactions.

1. Pure exchange: Pure exchange is an interaction where two elements, often one object and money, are exchanged without any other contact. It can be an auction system where the two

parties never meet in any direct sense and do not even know about each other. In this case the knowledge is totally embedded into the object. The object can include knowledge that is transferred to the buyer but in this interaction any development of new knowledge will never appear.

2. Minor social exchange: When we have interaction close to pure exchange but where the two parties have direct contact there are possibilities for the two to get to know each other and to develop personal sentiments in relation to each other. A consequence will be that they might prefer to choose each other in situations where other factors are similar. The object dealt with here can also include some knowledge and the only new knowledge that the interaction can create is the 'know-who' issue that the two parties learn about each other.

3. Technical exchange: In the third category the interaction includes the issue of what should be exchanged, i.e. the product or service and/or the facilities involved in the production or using of this product. The buying company might wish to have something adapted to its situation or the selling company wants to sell something that fits its production. The interaction includes the issues of how the object's interface with the buyer and the seller should look. The typical knowledge exchange is one-directed, i.e. knowledge is transferred in one direction. There is some learning or teaching going on. It will mainly be oriented toward know-how issues as it mainly will be about how to handle the process, but it will also include the know-who issue. The potential knowledge transfer will be centred to the object (product and/or service) and its features or the facilities and their features. The two parties can make adaptations in their internal way of functioning but there is never any deeper discussion between the two. However, the knowledge transfer might take place among several different functional managers and they can find their own 'internal' solutions. Still it is mainly devoted to technical issues close to what the two counterparts usually do. In addition to the know-how and know-who, it can also include more of know-why as the facilities and the products on the two sides are included. It is not possible to exchange sticky information in this category.

4. Co-operation: In the next category the interaction is broader and can include co-operative elements such as joint projects or the organising of special joint teams. It can regard technical items but also logistical or administrative ones. The two parties can have several joint projects going at the same time and they can include short term as well as long term aspects. Here we can and will have knowledge exchange of all types. From knowing what, to knowing who, and including sticky information. The basic ingredient in a co-operative approach is to be open to knowledge exchange. In the same way co-operative capabilities have much to do with handling information and knowledge. In other words knowledge is not just possible to transfer and create in co-operation, it is also vital for co-operation as well as for its result.

An important part of co-operation is to find new joint solutions that neither of the parties could have found in isolation. It means to create new knowledge of which some can be related to each party and possible to use in relation to others, but some might be more of a joint character and will be meaningful to or can only be used in the relationship.

5. Networking: Finally in the fifth type of interaction one or both sides also involve a third party in a systematic way. It means that interaction in this case deals with issues where all three (or more) involved actors have interests and where we can have all types of knowledge developing within and among the three. The main difference from 'co-operation' is that there are more than two parties directly involved. This creates a situation where there are three or more knowledge bodies confronting each other, which means that we get several interfaces where changes might appear. This affords greater opportunities to change several parameters, but it will also make the total knowledge exchange more complex to handle and to control.

In the above five categories there is a clear line between the second and the third category. More extensive transferring of knowledge and the development of joint knowledge between two parties is of special interest in the last three categories (3, 4 and 5) while it is more or less impossible to see as a result in the first two.

In the following sections we will look in more detail at each of these three categories for the construction companies and we will also include empirical illustrations drawn from earlier studies and from some exploratory interviews with top managers in Swedish construction companies. However, first the subsequent section will address some methodological considerations.

Methodology

As part of a larger program studying renewal in the Swedish construction industry we have taken on several different methodological approaches in an effort to capture some important driving forces and hindrances of renewal, and thus knowledge development, in the industry. As a first step we sent out a survey to more than 2,000 construction companies asking the business managers for their views on the knowledge content of their companies, how it is developed within the company as well as through interaction with subcontractors, various suppliers, and customers. More specifically the questions concerned, among other things, routines for skills development, the most influential actors in the surrounding network in regard to renewal, and also the most important

hindrances of renewal. Four hundred forty (440) completed questionnaires were received giving us an indication of these managers' views of how renewal takes place and how knowledge is created and transferred (Håkansson & Ingemansson 2011). However, in order to get a deeper understanding of the different processes through which this is done, and thus how interaction takes place, as a second step we also performed interviews with 12 business managers. These managers represent the four largest construction companies in Sweden (Skanska, PEAB, NCC and JM), some large to midsized construction companies (e.g. Veidekke and Einar Mattsson Byggnads AB), small construction companies, and small specialised contractors within roofing, excavation and foundation work, as well as one large contractor within heating and sanitation (Bravida AB). The interviews provide examples from different parts of the industry representing both large, midsized and small construction companies and different types of subcontractors. To carry out the interviews we used a structured interview form based on selected questions from the survey but the respondents were also encouraged to continuously discuss their answers and give examples of different projects or collaborations where renewal had taken place.

In addition to the survey and the interviews this paper is also based on empirical observations from earlier studies giving examples of different collaborative forms in the construction industry.

Knowledge transfer in the technical exchange category

In the technical exchange situation the companies interact mainly through their products and technical solutions. This is a very typical situation for the construction industry (Dubois & Gadde 2002; Bygballe et al. 2010). The construction process as well as the final object consist of many different technological solutions requiring technical information, and at the same time it is a very repetitive process making learning possible. The same actors continuously build very similar houses or roads or other objects and they are also meeting each other again and again. The products used have an important technological content and there are a number of different specialists involved who have important technological capabilities. Together the products and the technical services have to be combined in a special way to create a reasonable end result. This means that a technical exchange is constantly taking place through learning by doing in the combining of products and specific construction processes. The construction personnel have to learn how to use and utilise the products from the suppliers and also how to work together with the specialists from specialised subcontractors. The suppliers will, in the same way, meet the same counterparts again and again with similar types of problems and adapt products and services accordingly. This results in certain preferred solutions and that an important knowledge is developed especially in the areas where service is a major part.

Since many of the subcontractors are local or have a local organisational unit, an important local knowledge will be developed. In the same way there will also be an important object knowledge developed. There will be possibilities for both a local and an object specialisation that is often argued to exist in the construction companies. However, in both cases the possibilities for creating special joint knowledge with specific counterparts will be very limited.

This type of knowledge structure takes a long time to develop and will also be difficult to change. This was experienced by a Swedish construction company when it tried to change from frames made out of concrete to frames made out of wood for houses higher than two stories (Bengtson 2003; Bengtson & Håkansson 2008). Frames of wood in tall buildings have been forbidden in Sweden since the late 19th century after some devastating city fires. However, it has been allowed in the US where it has been demonstrated to be both safe and to reduce building costs. When the regulations were changed in Sweden, Skanska wanted to take advantage of these potential cost reductions. Despite the fact that there is a lot of wood knowledge in Sweden this proved to be a difficult task. The main reason was that the construction process, including a lot of sub-processes, was adapted to the 'concrete solution'. This included most components and the materials used. Over the years all the involved suppliers and sub-contractors had adapted their products as well as processes to the use of concrete in the frames. Different single suppliers were prepared to adapt to the use of wood if they were compensated, which in the end resulted in increased costs. The earlier learning was difficult to change, especially as there were no developed long-term relationships that could be mobilised.
This empirical example is interesting as it demonstrates the effect of learning over time in a situation dominated by 'technical exchange' while at the same time it also shows that this type of exchange is not at all enough when someone wants to make a change to this earlier learning.

Our survey shows that in general the use of prefabricated materials has increased during the last five years and in many cases this provides a good example of technical exchange situations. The prefabricated material or module is produced by a supplier and then delivered to the construction company that in turn uses it in its production of houses, industrial facilities or roads. In some cases the materials can be the result of long-term collaboration, but usually the prefabricated material is standardised from the standpoint of the producer's requisites and is then supplied to a number of different customers (the construction companies). All the business managers we interviewed, whose companies are involved in the production of residential and office properties, stated that prefabricated materials constitute a larger share of the total amount of materials used today than it did five years ago. One specific example can be taken from the company Johan

Svenssons Byggfirma (JSB), a midsized construction firm located and active in the south of Sweden. In the process of introducing a more standardised building process for three-story house buildings JSB needed to solve several problems in regard to more precise ways of assembling the different parts of the building. One key feature was a particular type of frame, called VST (after the Austrian company who patented the concept about 20 years ago -VerbundShalungsTechnik), which offered some interesting features. The different parts of the frame could be put together through a 'click-system' that reduced the time to assemble it and also kept the walls tightly sealed. This in turn reduced the energy consumption of the buildings. The solution provided the company with a more exact wall structure which, due to its features, made the construction process more efficient and less fallible. The VST frame in itself is quite an old concept as it was patented two decades ago but it didn't spread until much later making it a rather new solution, and in this situation new for the company (interview with manager). In this case the supplier of the frame is not making any specific changes to the product or taking an active part in further knowledge development. The user of the frame, on the other hand, is learning from the use of this product and adapting its production process as well as its end product to better fit the frame.

Another illustrative example of a technical exchange situation in our study comes from one of the largest construction companies in Sweden, NCC, and more specifically from one of its subunits, NCC Construction Sweden, which produces residential and office buildings, industrial facilities as well as roads. In an effort to increase efficiency during the last five years, the company introduced satellite controlled machines to perform large parts of the construction work in road projects. The machines are controlled via satellite through GPS technology but as the satellites are also used by the US military, the company is not allowed to use the satellites' full precision. This results in an error margin of plus/minus 20 meters. As this low precision was not acceptable on a construction site, the company brought in correction stations that compensated for the error. In large projects the stations are placed on the construction sites but there are also permanently placed stations in the Stockholm area, one of which can be found on the roof of the NCC main building in Solna. The introduction of this new technology drastically reduces the number of people that are needed on the construction sites and thus has had an impact on how these types of projects are planned and performed (interview with manager). In this case the use of a new technology, GPS for controlling machines, has changed the organisational structure of the projects in which it is used and has also necessitated the introduction of more equipment in terms of correction stations.

What is illustrated in the two examples from our study is that in this type of exchange situation it is primarily about using new technology and products, and learning from that use, rather than developing new knowledge or solutions. In the using setting both established products and processes can be altered to better fit the new technology, but little is done to the technology itself, and the changes that are made are usually concentrated to this context (even if there will be indirect effects affecting other actors). The next section will address the situation of two (or more) parties making changes and developing joint knowledge.

Knowledge transfer and creation of joint knowledge in the co-operation category

In the co-operation category there are possibilities for developing joint knowledge but also to transfer quite complex and sticky knowledge. The interaction is broad and intensive in these cases. Both sides take an active part and they can both learn and teach. Knowledge can also be confronted and new knowledge can develop through this interaction. The two parties can bring together different knowledge bodies and learn how to use them better vis-à-vis each other. But, it is required that the two parties are very clear about the need to work together for a certain time. This type of project is not very common in the construction industry. Several articles have described and exemplified the problems with developing such relationships especially in relation to suppliers (Gadde & Dubois 2010; Bygballe et al. 2010). A successful example, however, is described in Holmen et al. (2003), Holmen et al. (2007) and Holmen & Pedersen (2010). It is one of the major Norwegian construction companies that in 1998, within a larger project entitled 'Value creation in Collaboration', started the sub-project 'Networks with technical subcontractors'. In this project the company wanted to begin cooperating more closely with one or a few suppliers of three types of technical services: electrical services, ventilation services and plumbing services. The aim of the project was: "To develop a method for choosing and organising co-operation partners who will enable the firm to achieve competitive advantages. This should enable the firm to become better at: (1) choosing 'optimal' technical solutions for their customers, (2) handling interfaces among technical subcontracts and (3) utilising advantages stemming from co-operative relationships." (Holmen et al. 2003).

In the beginning the company invited three to five subcontractors within each of the chosen areas to discussions and the process ended with one being chosen for each area. This co-operative initiative was generally successful and resulted in positive outcomes for both the contractor and the sub-contractors. One crucial factor is the degree to which the sub-contractor incorporates this co-operation into its main marketing strategy, i.e. if it also applies the same strategy toward other customers. If so there are great possibilities for both sides to learn how to perform in a better way in relation to each other. But this also indicates the importance of the networking category, which is discussed in the next section.

Also, our empirical investigation includes some examples of close supplier relationships. For instance, the manager of one of the largest construction companies in Sweden involved in residential properties enlightened us of the both organisational and technical development they have carried out during the last few years. As part of a strategy to make both project work and production more efficient they are standardising materials, modules and working methods. As exemplified by the manager, instead of using a dozen different ways of assembling a wall in different projects, or using various different models for staircases, they have specified standardised modules and working methods that are now changing the way they work on the projects into a more systematic and consistent manner. In this standardisation process they reduced the number of suppliers they are working with and are also developing specialised solutions together with specific suppliers. One example is how the company realised the need to develop a balcony door that more straightforwardly could be mounted into the door frame. Together with their main supplier of doors they created a specialised balcony door that they now have started to use in all the projects where they apply this type of standardised construction (interview with manager). What we can see here is that there is a technical exchange in terms of new technical solutions being brought in but that there is also learning and development on a more long-term basis in which mutual adjustments are made.

There are also several examples of increased partnering strategies between construction companies and their customers in the Swedish case, which is also strongly indicated in our study. The CEO of one the largest Swedish construction companies claims that 20% of their total volume is done in 'partnering' relationships and that the larger share of their returning customers put partnering as their most preferred type of relationship form with their suppliers (interview with manager). In our survey, increased numbers of partnering relationships can also be identified as a type of renewal that takes place in different types of companies; small, midsized and large. JSB, a midsized construction firm mentioned above, works only according to this model in their production of residential and office properties. In addition, in co-operation with the customers (usually property owners) the company plans and constructs the buildings mainly from the standpoint of the actual users of the houses, apartments or offices, which means the people who are going to live or work in them. According to the manager they apply a more holistic approach in regard to who is actually going to use the building they are constructing, which in turn necessitates collaboration primarily with their customers, but also with various suppliers and subcontractors in the development of specific technical solutions. They find this a successful business model (interview with manager). This example illustrates how a company develops or expands its knowledge through co-operation with a specific party, in this case the customers. However, it is also indicated that co-operation between any two actors inevitably will affect other actors in the network, which in any particular case might involve technical exchange situations or further knowledge development for these parties and for the network. In terms of more systematic collaboration, this type of situation is dealt with in the next section.

Knowledge transfer and creation of joint knowledge in the networking category

In this category we have a systematic involvement of several actors. The importance of networks for learning within a project can be illustrated by a study of the construction of a commercial building in Sweden (Håkansson et al. 1999). In this study the main construction company and 30 of the most important suppliers and subcontractors were interviewed regarding, among other things, how much each of them had learnt from the project. An interesting network effect was identified. The conclusion was: "The case study very distinctively suggests that there is a much greater probability for a supplier to learn in a business relationship when it is connected to a number of the buyer's other relationships" (ibid p 450).

The reason is suggested to be that if there are a number of connections there will also be a larger number of interfaces where learning may appear. It can be between products, between facilities or between mangers with differences in competence and orientation. Here we can also see a network effect of the interaction categorised as technical exchange. As a number of actors are involved in dyadic interactions around the same technical solutions we get network effects in an organic way. Even when there are no direct network goals we will still get network effects as long as the involved actors are trying to improve in relation to each other. One problem with these effects is that they are more or less unconscious and that they are difficult to handle given the type of interaction applied.

There are few such examples of very systematic efforts in the construction industry. The cases we found in our study are related to the development of special platforms or standardised objects. There are also some regional examples mentioned. An interesting example, which was brought to us by one of the top managers, is that of a city in Northern Sweden in which the production costs for flats are lower than in any other city in the nation. The underlying reason is that since the 1960s the three main contractors in the city have all been using similar methods of building apartment houses that over time have become more and more alike. Today they are using the same basic principle and as a result both the personnel and the sub-contractors know how to deal with all problems. Together they have developed a local standard that reduces the total costs. Another empirical example from our study comes from PEAB, one of the largest construction companies in Sweden that, together with their subsidiary

Annehem, has created a concept with the same name for housing for senior citizens. The properties are architecturally drawn and offer specialised living arrangements in regard to the layout of the apartments, common visiting rooms and safety alarms. There are also a number of services connected to the properties that, among other things, include home help. The concept that the Annehem properties offer is made possible through collaboration between PEAB and a number of different suppliers and architects, as well as property owners and the different municipalities. The various actors that are connected to Annehem are developing the concept together, which includes both specialised products and services. There are also diverse business models through which the Annehem concept is offered, for instance as a rental where PEAB or another property owner owns the property and the municipality rents the common areas, or as tenant-owned flats where the tenants own the apartments as well as the common areas, and then purchase the additional services. As it is a standardised concept, PEAB, together with its collaborators, has managed to lower the production costs for these properties. Also, as PEAB can be the owner and the concept includes continuous services supplied by connected organisations and companies, the company is also involved in the long-term management of the properties. In this way, the company together with their collaborators learns what works for the tenants and what does not, which offers the possibility of adjusting current and future properties as well as additional services (interview with manager).

These examples demonstrate partly systematic efforts to achieve greater efficiency and lower costs through networking and the indirect network effects that come as a result of particular co-operation or technical exchange situations.

Concluding remarks

Exchanging knowledge is an important part of interaction. This is the starting point for this article. The ambition is to formulate in a more precise way how different types of interactions can lead to different degrees and types of knowledge exchange and to apply this to construction companies. We have classified interaction into five categories – from 'pure exchange' to 'networking' and for knowledge we have identified some special dimensions or features. In the next step we tried to identify and characterise what type of knowledge could be transferred for each category. We can conclude that some knowledge is transferred already in the first type of exchange – the knowledge that is built into the product. In level two there are also possibilities for learning about the counterpart and its way of functioning. In the third level there is also knowledge – especially technical – exchanged but usually only in one direction. Finally, to transfer any more substantial knowledge, or to transfer knowledge that is more complex and more embedded (sticky), there is a need for an interaction belonging to the last two categories – co-operation and networking. In these situations the interaction can also lead to the creation of new and/or joint knowledge.

Applying these general relationships between interaction and knowledge to the construction industry creates some interesting suggestions. In this study we identified a certain transaction pattern for the construction industry that has also been seen in earlier studies. The pattern is completely dominated by project-based transactions with counterparts who are rather well-known. This creates many possibilities of finding unique ways to combine the different counterparts in each project but there are several problems in using the same solution in several projects. Each project is handled as being unique in the sense that it usually takes place in a new location, which means that there are always local conditions to consider in terms of logistics, new suppliers and customers. The individuals can learn and bring the knowledge with them but as there will be other counterparts in the next project there are few opportunities for joint or collective learning. It also means that the value of individual learning decreases as there are problems with using it in the next project as the others involved do not have the needed complementary knowledge. Thus, the interaction among the involved actors in the construction industry is restricted due to the focus on projects. However, these problems are accentuated by the way the transactions are usually handled. There is a tradition of actively using competition for each and every project both by the construction company as well as its customers. One direct important consequence is that it makes only the three first categories of interaction able to be used in a general way. Another effect is that all involved actors only prioritise changes that decrease their own costs; all become internally focused and all become more interested in the economic consequences for themselves instead of finding optimal solutions for the totality. Thus, instead of continuous collaboration and mutual development, interaction becomes temporary within the time limited projects in which the different actors provisionally adapt to specific conditions and solutions in a way that is good for them.

One positive effect is that this makes it easy to be rather flexible in each project but it is problematic to use the learning over time. We get an intensive interaction directed to solving economic problems in each project but the only way the learning will be transferred to the next project is if this work results in a change in a product or in an institutional work program or project organisation. Furthermore, all such changes are difficult to implement as they then require that those involved in the next project are changing in the same way. In this way, the interaction in the construction industry gives some clear limitations as to what can be learned through others. As an effect, learning becomes slower, more costly and there are barriers of a systematic creation of joint knowledge. As a consequence, even though there is development of different standardised solutions, due to the above mentioned structure, there is a 'clash of logics' within

the construction network. While the material suppliers can reduce their costs by producing uniform products, and thus attain benefits of scale, the construction companies' use of these solutions still becomes rather costly as they constantly have to be made to fit with specific conditions, temporary solutions and counterparts. Thus, the coming together of different counterparts and solutions in each and every project create little economic incentive to develop specific solutions through mutual adaptations and long-term investments, which in turn hinders long-term learning. Instead, the type of organisational and technological development that mainly is taking place is that which can be handled internally. Therefore, learning has to be done stepwise and with one very clear and distinct initiator. Someone – a supplier or a buyer – has to make a conscious step and others will adapt if they see this step as successful. This creates an industrial system in which one product or organisational standard is replaced by another through 'development leaps' and where the new standards gradually have to be incorporated by others. This takes away all organic types of changes where learning and development occur as a result of continuous interaction.

We do, however, also see examples of knowledge production that corresponds to the co-operation and networking categories. In these examples the actors are involved in continual learning situations with the purpose of developing not only specific technical solutions but also their internal activities on a more long-term basis. This can be observed particularly in the networking cases where the aim is to establish a more efficient and knowledgeable organisation through interaction with other companies and organisations. However, it also applies to the co-operation examples that indicate that construction companies in any particular case can interact and learn from both specific suppliers and customers. As stated in the beginning of the paper, examples of this type of interaction and learning are rare within the construction industry. This indicates that the way in which the construction sector is structured is creating problematic locked-in effects in terms of how interaction can take place and consequently what can be learned from others. Instead of continuous interaction and mutual adjustments, the companies are trying to handle most of the development internally which results in standardised inter-organisational interfaces and difficult stepwise development and integration of new solutions as well as learning.

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