

Technological Development in Construction: Preaching to the Converted or Seducing the Disbelievers

This paper is a draft version of a paper accepted for the Journal of Knowledge and Society

Ariane von Raesfeld
Faculty of Technology and Management
University of Twente, Box 217
7500 AE Enschede
The Netherlands
Email: a.m.vonraesfeldmeijer@sms.utwente.nl

Abstract

The paper analyses the successes and failures of the transfer of technical innovations into the Dutch construction industry. When in the nineteen-seventies calcium silicate stone was introduced as the basis for a new construction technology, it rapidly became the material of choice for housing construction in The Netherlands. More recently the Dutch government has been promoting timber frame construction as a sustainable alternative to conventional construction methods. The adoption of this method by the industry, however, is slow. The paper argues that differences in technology transfer practices in both sectors account for the differences in their relative success. It views technology transfer as a result of alignment processes between technical configuration and social effects; or, in other words, between form and function of a technology. Alignment, then, is not a purely technical matter. It involves tension and interaction between insiders and outsiders of a network; between those who develop, those who build, those who regulate, and those who use a technology. By describing and analysing these processes of alignment in the timber frame and calcium silicate stone construction sectors in the Netherlands, the paper aims to understand to what extent the adoption of construction methods can be anticipated and how it might be advanced.

PROLOGUE: PREACHING TO THE CONVERTED

Wednesday, June 21, 2000, 11:00 AM, in the Van der Valk Hotel at Schiphol, Piet van Houten¹, project leader at the *Centrum Hout* (the Wood Center), welcomes participants to the yearly Dutch Timber Frame Construction Day. The Wood Center promotes public education, research, and knowledge transfer, in order to foster the responsible use of wood in the housing construction industry. In the morning, the participants will visit two construction sites. In the afternoon, presentations will show the timber frame method from the point of view of the architect, the commissioner, the resident, and the supplier. By 5:00 PM, at the reception, I witness a discussion between Piet van Houten and Siebe Huizinga. For a year now Siebe has been organizing excursions to timber frame construction sites in Aalsmeer and in Alphen – two fast-growing cities in the green heart of the Netherlands. Siebe wonders why so few people from housing associations, and hardly any real estate developers or construction companies are attending the timber frame day. They are, after all, the principal players who make the decisions about which construction methods to use in new building projects. According to Piet large construction firms and the associated real estate developers are not a crucial group to target because they have a “pavlovian response towards concrete” anyway. Siebe points out that: “the architects who are here today already know about the aesthetic and design advantages of timber framing and the people who are now having drinks here are employees of timber frame construction companies who know about the technical characteristics of their products. Today the timber frame sector has been preaching to the converted.”²

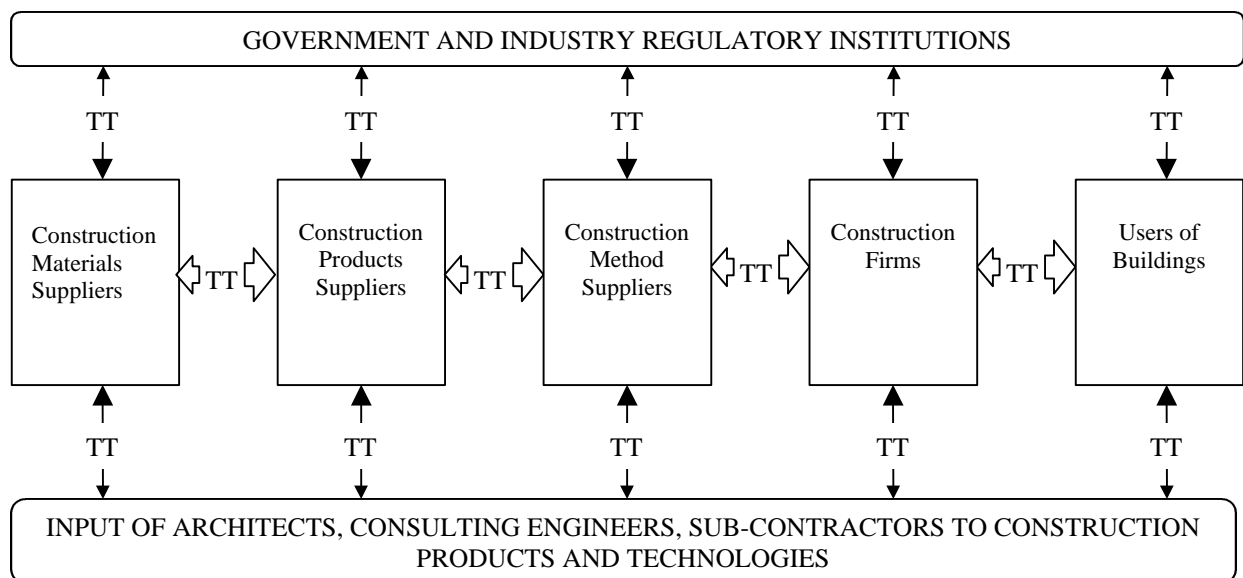
INTRODUCTION

This paper analyses the successes and failures of new technical innovations in the Dutch house building sector. When in the nineteen-seventies calcium silicate stone was introduced as the basis for new construction technology, it rapidly became the material of choice for housing construction in The Netherlands. More recently the Dutch government has been promoting timber frame construction as a sustainable alternative to conventional

construction methods. However, the adoption of this method by the industry and by the public has been slow.

On the face of it, timber frame construction is an attractive building technology. Sustainable, affordable, and aesthetically pleasing, it would seem to mesh with the emphasis on sustainable environmental policies and on urban planning strategies that are both cost-sensitive and innovative, that emerged in The Netherlands after the second world war. However, the adoption of new technology does not depend on its intrinsic qualities alone. Housing construction entails transformation, in the user arena, of the building technologies that are developed by supplying industries.³ Thus, many different players are involved in the processes of design, engineering, coordination, and integration of technology, including architects, consulting engineers, contractors, sub-contractors, and suppliers of materials, products and methods. Moreover, successful technology transfer in construction involves close interaction among these players. For example, construction firms and architects have to specify their requirements and work with suppliers to make the specifications of a new product fit their needs, but also, for new products to function architects and construction firms have to bring their working methods into harmony. As a consequence technology transfer within the construction network exhibits a complex pattern (see figure 1) of upstream, downstream, and intersecting relations between regulatory institutions, various users, suppliers, and construction firms.

Figure 1: Technology transfer (TT) in the construction network.



TT = Technology Transfer

This article investigates the adoption, after the second world war, of two new construction methods in Dutch construction. It looks at the strategies that were used to calibrate the new construction technology to diverse housing (and other) needs of different players. Its examination of the adoption of, respectively, timber frame and calcium silicate stone construction shows how implementation strategies and practices that are specific to each case drive the technology transfers that take place and the degree to which the technologies are adopted in the wider community. The application of technology is, after all, both the target and the test of the technology transfer process. That is to say it is only when actors put new technology into practice and use it to achieve values, that transfer can be said to have taken place. The position of players in the construction network, their relationships with users, and their ways of gaining profit all affect their incentives to apply a new technology – or not. Technology transfer, then is not a guaranteed, nor an uniform process by which good technology inevitably finds its way into the world.

This article tries to understand the mechanisms of technology transfer in Dutch housing construction by articulating and comparing the relationships and implementation processes that developed between the suppliers of the two construction methods and the user-builders⁴ that were – and are – involved in housing construction. It argues that differences in technology transfer practices in both sectors account for the differences in their relative success. It views technology transfer as a result of *alignment processes* between technical configuration and social effects; or, in other words, between form and function of a technology. Alignment, then, is not a purely technical matter. It involves tension and interaction between insiders and outsiders of a technical regime; between those who develop, those who build, those who regulate, and those who use a technology. By describing and analyzing these processes of alignment in the timber frame and calcium silicate stone construction sectors in the Netherlands, the article aims to understand to what extent the adoption of construction methods can be anticipated and how it might be advanced.

HOUSING CONSTRUCTION IN THE NETHERLANDS

Driving through The Netherlands one may observe that the Dutch seem to prefer single-family dwellings that are made of brick on the outside, with tiles on the roof and wooden doors, window frames, and stairs. Clearly this preference for low-rise buildings and traditional materials and construction methods contributes to the village-like appearance of Dutch cities. One might wonder why all the houses look so similar, and one might think that the Dutch are of one mind as to what a house should be like. This similarity, however, originates from a particular feature of housing in the Netherlands, which is not observable on sight, 44% of the housing stock is owned by non-profit organizations that rent to the public.⁵

Public housing, then, has played a crucial role in the orientation of Dutch architecture, in the quality of housing, and in urban development. While housing requirements and construction methods have sometimes developed through initiatives of residents, more often housing associations, architects, government, and large construction firms have taken the lead. Research institutes, advisory boards, and supporting committees, all operating on the production rather than the consuming side, are the dominant players that determine the scope, scale, and practice of housing construction in the Netherlands.

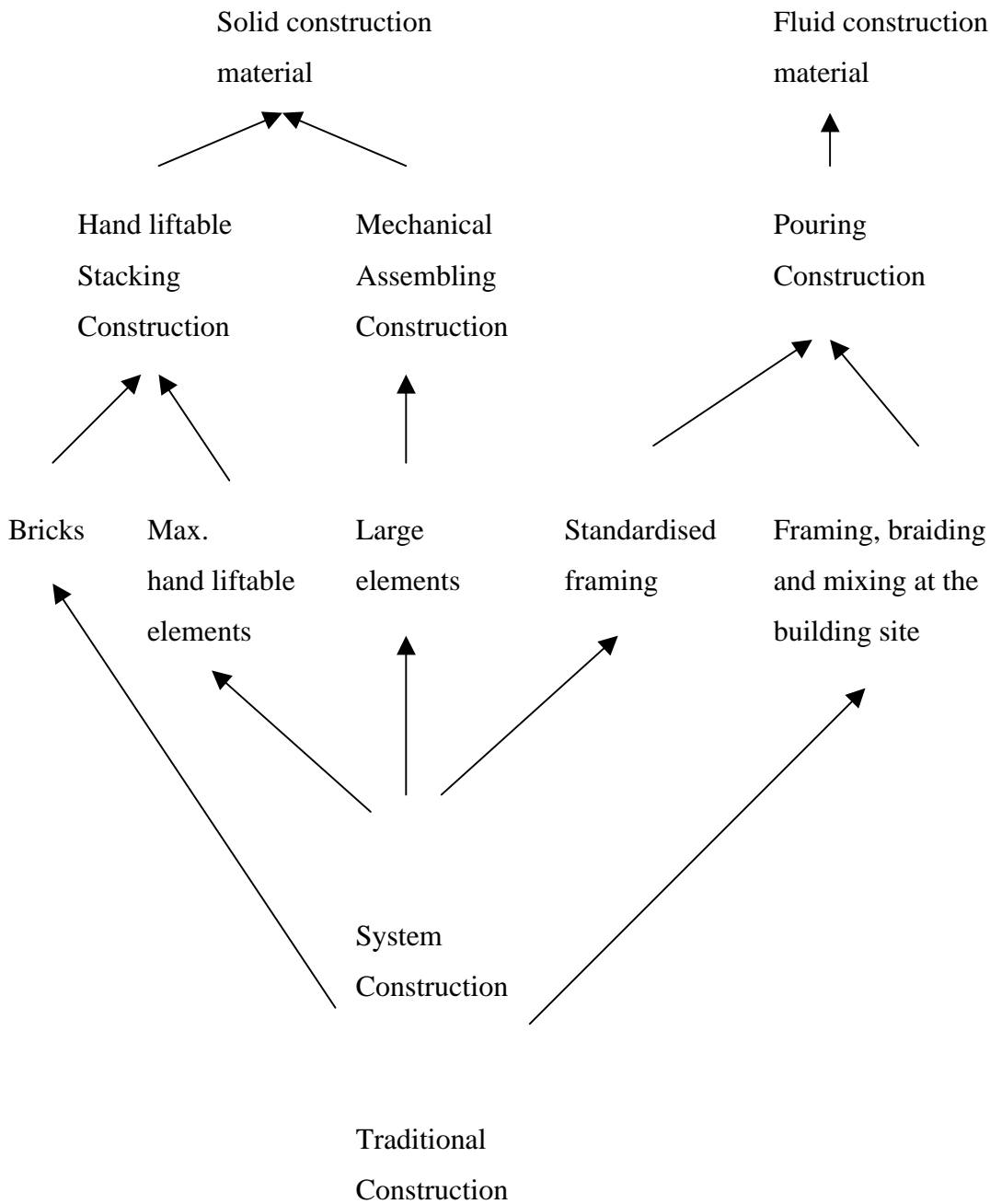
However, in looking closely at the construction regimes in the Netherlands, the picture turns out to be rather more complex. For while consumer interest groups, varying from the *Nederlandse Vereniging van Huisvrouwen* (Dutch Association of Housewives) and the *Vereniging Eigen Huis* (Association Own House), to committees of residents and the squatters movement, have at times provided an effective counterbalance to these technocratic housing organizations, relative outsiders, such as suppliers of construction materials and developers of construction methods, have also influenced the innovative directions taken in the Dutch housing industry.

After World War II the Netherlands had to be “reconstructed.” Facing the shortage in available housing, and recognizing the need to build in large numbers at a reasonable cost, the government promoted the rationalization and industrialization of construction. While initially prefabricated houses were promoted as the solution to the

issue, over time other forms of construction, such as pouring concrete systems, won the day.

At present three basic construction methods are in use: stacking construction; assembling construction; and pouring construction (see figure 2).

Figure 2: Technical paths of constructing a building (adapted from Priemus & Van Elk, 1970)



In “stacking construction”, materials are processed at the site, as in traditional brick building with masonry walls and wooden beam layers and as in non-traditional calcium silicate stone building where elements are glued together. “Assembling construction” is characterized by prefabricated construction elements that are delivered at the site, as in timber frame building with prefab wall elements, prefab wooden or concrete floor elements, and an outer surface of wood or brick. In “pouring construction”, fluid concrete is processed at the site, either involving standard framing or involving framing, braiding, and mixing at the building site. Large constructors use poured concrete for large series production. Small constructors use calcium silicate stone for both small and large series production. Freestanding private housing, often offered by catalogue, represents the dominant use for timber frame construction. This state of affairs is reflected in the market shares of different construction methods (see Table 1).

Table 1: Market shares of construction methods used for housing, commercial, and industrial building (source Hügli Pollock, 1999)

In %	Timber frame	Brick	Calcium silicate stone	Concrete	Cell-concrete	Other Material ⁶
1996	2%	4%	61%	9%	1%	22%
1997	2%	4%	60%	9%	1%	23%
1998	3%	4%	56%	11%	2%	23%

The housing shortage and its consequent demand for inexpensive, fast-building, and efficient construction technology engaged a variety of players – among whom the Dutch government was *Primus inter pares*, developing construction policies and providing subsidies to promote the building of affordable housing. The housing situation after the second world war thus framed a socio-technical environment that was particularly conducive to the development of a thriving construction industry. As a result of technology developments and technology transfers, significant innovation in construction methods ensued.

Two such innovations, timber frame construction and calcium silicate stone construction, both with roots in the nineteen-fifties, developed according to very different

trajectories in the following years. Both sectors would begin to ride the crest of the wave in the nineteen-seventies, when the focus shifted from large-scale efficient production to small-scale production with a request for differentiation and variation in housing. Compared to building in concrete the two new construction methods enabled much more variation. However, both methods were introduced and advertised to customers much earlier – and by different strategies. While calcium silicate stone suppliers targeted small and medium sized construction firms, timber frame suppliers mainly focussed on selling houses to private owners. Calcium silicate stone suppliers were thus dealing with the actors who made the actual choice of construction method for a large portion of the Dutch housing market, whereas timber frame suppliers were connecting with a group that did not represent (and never has represented) a significant part of the housing interest in the Netherlands. While in the first case the actors assumed an active role in working together with construction firms to make the construction method cost-efficient, thus adding value for their customers, in the second case there was no such incentive and the timber frame suppliers ended up selling standard houses to end-users. In comparison then, one might say that the calcium silicate stone sector focussed on tailoring their construction practices to the function it had for their customers (i.e. the provision of cheap materials and methods), while the timber frame sector focused on developing the construction method in correspondence with their own production purposes and constraints.

During the nineteen fifties and sixties some firms began to experiment with timber frame techniques.⁷ Later, in the nineteen-seventies, a new Canadian technique of timber frame construction was introduced in The Netherlands. Initially the use of the new method was explored in large construction projects. These experiments were followed by a surge of free standing houses, row houses, catalogue villas, fill-in projects, and finally by the introduction of the multi-story timber frame building. Architects and institutional customers became familiar with the building method. In the nineteen-nineties the government adopted *Actieplan 20% meer hout in de bouw* (Milieuberaad Bouw 1995), a sustainable construction policy that provided a stimulus to position timber frame construction as a fully-fledged building method. The plan aimed at increasing the use of wood construction by 20 % within 5 years. Because wood is renewable and binds CO₂

during its growth, it was considered an environmentally responsible and sustainable material. Despite those efforts and considerations, the market share of timber frame construction in the Netherlands remains at a mere 3%.

Construction methods based on calcium silicate stone technology, by contrast, take up about 56% of the Dutch building market; calcium silicate stone is the most widely used housing construction material in The Netherlands. Its widespread use is due not only to the intense construction activity that followed the end of the war, but also to close cooperation among manufacturers and between the manufacturers and other players in the construction network. In 1947, in order to decrease competition, the *Centraal Verkoopkantoor voor de Kalkzandsteenindustrie* (CVK, central sales office for the calcium silicate stone industry) was established, of which all fifteen Dutch producers became members. Initially the association's focus was on distribution and price control. But over the years its attention has shifted towards facilitating collaborative technical developments in the calcium silicate stone industry. In time the assortment of calcium silicate stone products has increased and changed. Whereas in the past calcium silicate stone products had been designed to imitate conventional and commonly used brick products, by now the calcium silicate stone concept has developed a character of its own, more closely representing the technical properties of the raw materials. In collaboration with construction firms, special material handling equipment and wall finishing methods have been developed as well. Calcium silicate stone housing, then, can be considered a successful post-war innovation in the Dutch construction industry (Pries 1995).

In the following I lay out the differences in implementation and development strategies in the two construction sectors in more detail, with the aim of understanding mechanisms of technology transfer in Dutch housing construction. I consider technology transfer in terms of the alignment of form and function of a technology, and propose that the analysis of alignment of form and function in those two sectors offers a view of the mechanics of technology transfer.⁸ By articulating and comparing the relationships and alignment processes between suppliers of two construction methods and the user-builders who are involved in construction, we will be able to identify tensions in the alignment between form and function. Such tensions have to be solved in order for transferred technology transfer to endure, and I claim that one of the big differences between the two

construction methods is that one understood and actively tried to solve such tensions, while the other remained oblivious to them for a long time.

ALIGNMENT OF FORM AND FUNCTION

Over the years technology transfer in Dutch housing has been strongly influenced not only by the government but also by a continuous debate between a variety of other stakeholders about the technical form and the social function of housing (De Vreeze 1993). Technology transfer in the housing construction area, then, is an interaction process among concerned stakeholders. Successful technology transfer is necessarily an act of appropriation and, whether it involves the implementation of a technology or its acceptance in a local situation, it entails certain transformations. Because of such transformations, technology transfer is an innovation in itself (Rip 1999).

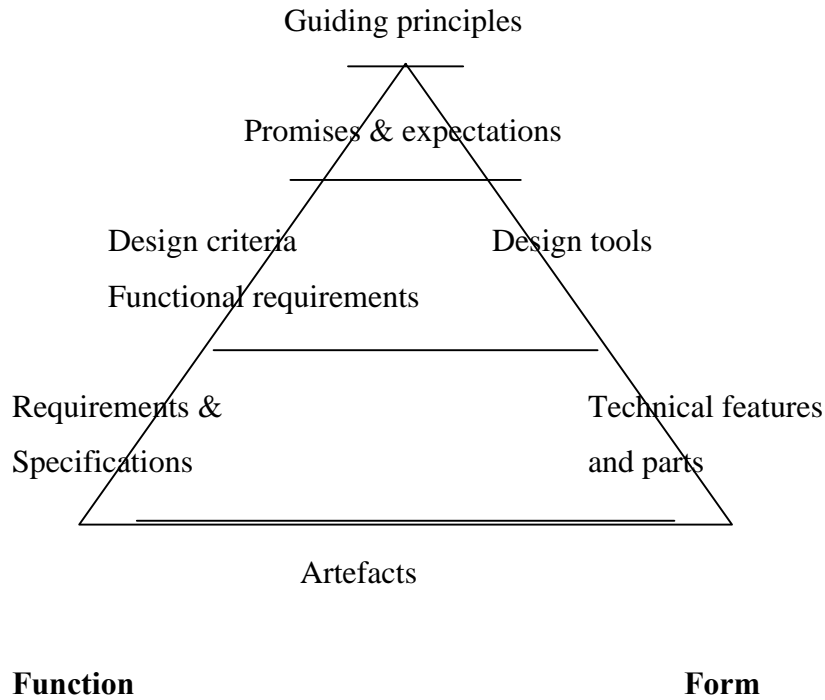
In a seminal paper on design hierarchies and market concepts Clark (1985) suggests that a pattern of innovation depend on how technology and user requirements link up – or on how form and function *align*. A technology's functionality as it was formulated and intended by the initiator – and as it is materialized in the particular form that a technology takes – does not necessarily map onto user requirements – and to the functionality that the user ascribes and extracts from the technology – (Rip 1995). In order to effectively carry out technology transfer it is necessary to *make* form and (social) function of a technology match⁹.

We should not make the mistake of thinking that the alignment process involves only a simple maker/end-user relationship, however. Admittedly, in innovation studies it is usually the end user/technology alignment that gets the most attention – as in Pinch and Bijker's (1987) bicycle case in science and technology studies; Abernathy and Utterback's (1978) life cycle theory; Burgelman's (1983) and Dougherty (1996) market-technology linking; and Von Hippel's (1986) lead-user approach. But form-function alignment mobilizes more parties than the user-inventor pair. Arguably – and as the construction cases unmistakably show – technology is embedded in an industrial network; its development is an ongoing process in which the technology is constantly aligned and realigned to a web of different actors.

Rather than being transferred from producer to user, then, technology moves between a variety of users, modifiers, and producers, whose needs and values are likely to diverge. In addition to the business environment (dominated by exchange relationships between customers, suppliers, and research institutes), there is the regulation environment (dominated by government and regulatory bodies) and the wider society (with consumer organizations, environmental groups, public opinion leaders, media, and independent scientists) (Deuten et al. 1997). Given the multi-functional requirements in a network, in order to accomplish successful technology transfer, the features and benefits of a new technology must be conceived, articulated, designed, and “operationalized” (brought into existence) in a multi-dimensional way.

In the description of the two construction methods that I provide below I consider technology transfer an interaction process among concerned players in industrial networks who aim to align the form and function of building technology. The efforts at alignment involve mutual inter-organizational learning, in the first place between the users and the suppliers of the technology and in the second place between actors outside the user-supplier relationship. Such learning is driven by tensions: technical tensions between function and structure of a technology (such as walls cracking due to misfit between calcium silicate stone elements and the mortar used);¹⁰ socio-technical tensions between social function and form of a technology (such as standard timber frame wall elements limiting architect’s design freedom);¹¹ socio-technical tensions in the industrial network between suppliers and those who use, install, and maintain a technology (such as construction firms that have no experience with construction calculations for buildings made of calcium silicate stone, while real estate developers request to use them in small series construction because of its cost-efficiency); and societal tensions between insiders and outsiders of construction regimes (such as government requesting more sustainable construction methods).

Figure 3: The Triangle of Technological Development (Van der Poel, 1998: 17)



So, the simple phrase, “alignment of function and technical configuration” covers complex processes, negotiations, and work. Van der Poel’s triangular model of technological development (Van der Poel 1998, see figure 3) provides a visualization of this complex process, detailing the different levels at which function-form alignment takes place – from the experiences on location to the interactions and negotiations at the global level of the regime. My description of the alignment of function and technical configuration of the timber frame and calcium silicate stone construction systems follows Van der Poel’s model, by focussing on tensions among the different layers of the triangle. A comparison of the two construction systems shows how alignment strategies are different in each sector, and how they might account for the constraints on and the opportunities for the appropriation of new construction regimes.

TIMBER FRAME CONSTRUCTION

Technical Features

Timber frame is used to construct houses, apartment buildings up to five stories, and commercial and industrial buildings. Timber frame inner walls form the bearing construction. The outside wall or façade can be realized with different materials : brickwork, plaster, wood, sheets, or ceramic material. The wall elements consist of softwood post and rail work, filled with insulation material and covered with sheet material. Physical functions such as thermal and acoustic insulation, damp transport, and fire resistance are integrated in the build up of the wall. From the inside, the wall elements are covered with plasterboard to finish the wall and to insure fire resistance. For the sake of stability, sometimes the outside walls are covered with wooden sheet material. To prevent condensation in the wall element and to preserve airtightness the outside is completed with a damp inhibiting foil.

Publications issued by the timber frame sector emphasize a range of positive technical features of the construction method (e.g. Banga and De Groot 2000a). The four most recurring features mentioned in those texts are energy efficiency, efficient building process, design freedom, and easy compliance to government regulations. Let's take a closer look at each of these features. First, the world-wide emphasis on CO₂ reduction expresses a need for energy efficiency in buildings. The timber frame sector holds that improvement of the insulation value of the external shell of a timber frame element adds minimal extra costs, especially when compared with the cost of concrete and calcium silicate stone construction. Second, improvement of construction efficiency is always on the agenda of contractors. According to the timber frame sector, the prefabrication of elements allows for fast assembly and short construction time and thus lower building costs. Third, design freedom – the capacity to differentiate buildings – is valued by architects and end users. The timber frame sector asserts that since there is almost no thermal leakage in timber frame construction, it is easy to make overhangs, curved shapes and add-ons, so that there is more design freedom than other construction systems allow. Finally, regulatory requirements on durability, fire resistance, acoustic insulation, and

sustainability can easily be met, according to the timber frame sector. However, as the market shares in table 1 suggest, even with those attributes timber frame construction has failed to become a leading construction method.

Why is a proven building technology such as timber frame construction not widely used in the Netherlands? An answer to this question may be found in the strategies for the alignment of form and function that the timber frame sector has deployed.

Aligning Form and Function in the Timber Frame Industry

In the nineteen seventies and eighties timber frame suppliers focussed on providing variation and differentiation at an affordable price. In the nineteen nineties a second peak in timber frame construction was related to the increasing demand for sustainable and energy efficient houses.¹²

At the end of the seventies, in search of building methods which could provide more variation and differentiation at an affordable price, 'Wilma' (De Vlieger 1980), one of the larger Dutch housing construction companies, began to look for alternatives to traditional building methods. Wood, a construction material widely used in Scandinavia and North America, came into focus and they sent company representatives on study trips to Sweden and Canada. At the time the prefab timber frame systems were used in Swedish free standing houses only, while in Canada timber frame was used in urban development, for high density and multi-story construction. In line with cramped Dutch conditions, Wilma concentrated on the Canadian method, which was more appropriate for suburban development with its modular construction and standardized sizes. The company was especially interested in learning the ropes about using the method and established relationships with three renowned timber frame architects in Vancouver. In 1979 the construction of 260 houses in the urban development area, Nieuwegein, began with two Dutch architects and one Canadian architect co-operating in the project. Throughout the project, there was close contact with local, provincial, and national governments, as well as with experts from the Dutch wood information institute and consultants from Vancouver. A vocational training program for construction personnel

was developed; Canadian timber frame specialists came to train Dutch instructors. Work on the first 50 houses was completed by Canadian construction workers in collaboration with Dutch volunteers who had taken a timber frame construction course.

In the early eighties, several construction firms began using the timber frame method. Nevertheless timber frame construction remained a new technology in Dutch construction practices and lack of expertise with the materials and methods led to mistakes and defective buildings. Furthermore, ambiguity in regulatory requirements on fire resistance, acoustic properties, and the like required close cooperation among the architect, local government, and customer, making the method less appropriate for construction firms to get a building commission via open procurement¹³. Therefore, two issues became important: establishing acceptable quality standards and aligning the method's technical aspects to existing regulations.

In 1984 timber frame constructors and producers founded the *Vereniging van Houtskelet Bouwers* (Dutch Association of Timber Frame Builders). Its first task was to solve the quality and regulation problems. To meet this task the association focussed on improving the transfer of knowledge, developing norms and prescriptions, stimulating research, and seeking publicity for the method. With respect to regulations, cooperation with the wood inspection foundation resulted in two new quality marks, one for the timber frame construction method and another for the production of timber frame elements. By now, in order to be allowed to build under the associations auspices, all members of the timber frame association must possess a “timber frame construction product certificate” and an “attest” that describes the system used by the firm, a judgement on its past performance, and a note on its record of compliance with the Building Decree¹⁴.

Centrum Hout (Wood Center), another timber frame coalition, initiates publicity, research, and knowledge transfer. The Center's activities focus on promotion, information, education, and research to improve the reliable application of wood. *Centrum Hout* is financed by organizations such as the Dutch timber frame association, the association of Dutch wood enterprises, the association of carpenter factories, the wood unions, the association of wood importers, and the association of wood agencies.

Representatives of the center give guest lectures at technical colleges, and a telephone helpdesk provides advice on wood application to the construction industry.

Recently, within the frame of the Dutch action program of “20% more wood in construction,” *Centrum Hout* has put great effort into the knowledge diffusion project, “Multi-story timber frame construction” (De Groot 2000). The project has yielded articles in construction journals (e.g. De Groot 1999; Dubbeling 2000), a general brochure on timber frame construction (Banga and De Groot 2000a), a new revised manual on timber frame construction (Banga and De Groot 2000b), excursions, and several symposia. Furthermore, project cost and environmental studies were carried out comparing an actual multi-story timber frame project with calcium silicate stone and pouring concrete construction alternatives (Van der Breggen 1999). These studies conclude that while timber frame construction is a little bit cheaper than traditional construction methods, it is much more sustainable.

In 2000 *Centrum Hout* developed a series of reference details for timber frame construction, together with *Stichting Bouw Research* (Construction Research Foundation) and the Association of Timber Frame Builders. The reference file includes drawings of construction details that are directly applicable, in compliance with the Building Decree, and checked for physical construction performance.

In order to transfer knowledge and increase the visibility of timber frame construction *Centrum Hout* provides company training and education upon request, organizes a yearly timber frame day with presentations of R&D activities, and publishes about demonstration projects. Unfortunately, at the timber frame day, the attendance of housing associations, large construction firms, and real estate developers is low. In the realm of education a similar pattern can be observed: it is mainly members of the Timber Frame Association who make use of the tailor-made courses developed by *Centrum Hout* (Centrum Hout Annual report 1999:10).

Large constructors and real estate developers are not integrated in the timber frame sector. For the timber frame sector to increase its market share would require the inclusion of and an alliance with these parties. Not only because large construction firms and real estate developers form the largest group to commission construction projects today, but also because these parties’ negative opinion about timber frame houses will

continue to negatively impact the construction field tomorrow. When, as can be foreseen, in the coming years new construction activity will shift from large suburban development to renovation of the cities, housing associations will be a third group to exert significant influence. At the timber frame demonstration projects the housing associations constituted the largest group of visitors (73% in Aalsmeer and 62% in Alphen), which may cautiously be counted as a good sign for the timber frame industry. (Kats 2000).

Interviews and publications about construction projects show that real estate developers and traditional construction firms prefer to use concrete (De Vries 1999: 17). Even their customers, who are sometimes very much in favor of timber frame, do not succeed in making a difference (Priemus et al. 1999: 23). Real estate developers often argue for brick or concrete because “[m]ost people in the Netherlands who are looking for a house do not consider timber frame building as durable” (Schuyt 1999: 51). Whether this is fact or fiction is not clear; experience shows that when buyers have a choice, as in the case of free sector houses in rural areas and redevelopment in city centers, they often choose timber frame houses. It is clear, however, that in large urban development projects the final buyers – and thus the end users – do not determine which construction method is used.

Another reason why real estate developers and the associated construction firms do not want to build timber frame houses is because they consider it financially unattractive. The afore-mentioned study initiated by the *Centrum Hout*, however, comparing the costs of timber frame construction, those of pouring concrete, and calcium silicate stone (Van der Breggen 1999), indicated that timber frame is marginally cheaper than concrete and calcium silicate stone is the most expensive option. Timber frame saves costs because it requires a lighter foundation and because the prefabrication process allows a shorter construction time. In the particular project under study, an additional advantage of timber frame was that the lighter foundations provided more parking space in the basements, thus reducing the average cost per parking place. Obviously, in city centers where parking space is scarce this aspect generates value. Nevertheless, construction firms and developers are not convinced. In the light of their history this is no surprise. Having adopted concrete in the nineteen-sixties as the building material of choice, they have since developed concrete construction as a highly efficient method,

investing in expertise and equipment that enable building in large series with minimal variation.

Besides these considerations of ideology and technological routine, we should consider the history and constitution of the Dutch construction industry in order to explain the niche position of timber frame. The majority of construction firms are small and medium sized enterprises that work with basic materials and traditional craftsmen.¹⁵ Although this situation is changing as a result of high production demand and low availability of craftsmen, there is a real tension between traditional, on-site construction activities and timber frame, factory-based design and manufacture that only requires assembly at the construction site. Solving this tension calls for adaptation and development by all the parties involved in the construction network.

This description of alignment activities shows an emphasis on solving tensions between function and structure of timber frame construction. The timber frame sector has focussed on improving technical features in relation to government regulations and quality standards of production and products. The arena in which changes and modifications take place has largely been the timber frame sector's own constituency of already converted enthusiasts. Little effort has been spent on understanding and alleviating outsider's demands, predispositions, and concerns –such as those of real estate developers and construction firms. The timber frame sector, one might say, fails to align or enroll its enemies. The alignment then stalls, and the timber frame sector does not succeed in acquiring a larger part of the construction network involved. As we shall see in the next section, the calcium silicate stone sector has been much more successful in aligning various players with their construction methods. This is in part because it has made a successful effort to solve the tension between traditional and industrialized construction – a tension that has turned out to be one of the frailties of timber frame construction in the Netherlands.

CALCIUM SILICATE STONE CONSTRUCTION

Technical Features

Calcium silicate products are applied in housing and industrial construction for foundations, cellars, load- as well as non load-bearing inner walls, and for outer walls. Until 1957 the calcium silicate industry made calcium silicate stones in traditional brick sizes. After 1957, with the introduction of a new generation of presses, larger size building blocks came on the market. Presently the product assortment consists of stones in traditional brick sizes; mortar blocks of various (but standard) thickness, width and length; glue blocks of the same standard sizes, with finished or non-finished sides; heat wall elements; and standard elements of various sizes (CVK, 2000). Furthermore, rim blocks are available, that may function as a fitting strip and surface for the elements and blocks. Blocks and elements have lifting holes at the top for mechanical handling. To keep the pieces together, instead of traditional cement, special glue-mortar and glue equipment is used.

Aligning Form and Function in the Calcium Silicate Industry

While in the nineteen-seventies and eighties the timber frame sector stressed variation in house types the calcium silicate stone sector focussed on reducing cost at the building site. In the nineteenseventies, construction cost were the object of heated debate. While the common view was that concrete building was cheaper than traditional building, the *Centrale Verkoopkantoor voor Kalkzandsteen* (CVK, central sales office for calcium silicate products) put great effort in proving that calcium silicate construction methods were much more cost efficient than concrete construction. Though costs are still a leading principle in construction, lately environmental aspects of construction are gaining more weight. In anticipation of this development calcium silicate industry has been developing and distributing information on the environmentally friendly characteristics of calcium silicate stone constructions (CVK 1996).

CVK's leading strategy is to develop the calcium silicate regime through the training of architects, structural engineers and contractors and through the promotion of R&D cooperation among producers, CVK, the calcium silicate research center, and external research institutes. While before the second world war the calcium silicate industry had to fight its image as an inferior brick producer, after the war its focus shifted from making pseudo bricks to making a product that fully deploys the properties of calcium silicate. The producers, CVK, and the calcium silicate research center joined efforts to improve the efficiency of processing calcium silicate products at the building site. In order to develop the handling equipment, they started collaborative projects bringing together heterogeneous partners such as technical universities, research institutes, *Ratiobouw/bouwcentrum*, *TNObouw*, local governments, and the labor inspection agencies. Besides these R&D activities another important activity was, and still is, providing advice to the construction industry about the application of calcium silicate products at the construction site.

In 1960 "Construction in calcium silicate stone" (Klein 1960) was published. CVK considers this book a standard manual for every housing construction firm. To promote the book CVK hired two sales promoters to visit architects, contractors, and retailers; 8,000 information folders were made, journal articles were written, 1,600 contractors visited CVK's lectures, and the motion picture *From Chalk and Lime to Stone*" was made. Most of these activities had a unidirectional promotional character, targeting retailers.

In the nineteen-eighties a change in direction occurred with the development of the "K-400" housing concept. While K stood "voor kalkzandsteen en dus voor kwaliteit" (in favor of calcium silicate stone and thus ... in favor of quality), the 400 indicated the rental price of the houses¹⁶. Although an intensive publicity campaign accompanied the "K-400" houses, only 100 were built. Nevertheless, in the process CVK learned to cooperate with the construction industry. According to L.G. Klein, who has been active in CVK sales since the seventies, "[f]or the first time we sat at the table with construction firms. They told us all about the construction process and we learned a lot" (Ultée 1997:84).

Nowadays advice on construction with, and processing and handling of, calcium silicate stone is freely and widely available. Moreover, upon request CVK offers on-site building assistance. Until today CVK gives information on various subjects, such as the application of elements; acoustic insulation ; processing calcium silicate products; and environmental aspects of design, construction and living in calcium silicate stone.

Today, the calcium silicate industry with its 60% market share is an insider in the construction network. However, this has not always been the case. Before the second world war brick masonry was the dominant construction system; for some time after the war concrete ruled. As late as 1983, according to CVK director Van der Poel in a radio talk, public opinion favored concrete; “in this country the widespread myth is that pouring concrete is cheaper than traditional construction” (Ultée 1997). In that same year, however, the Dutch *Centraal Bureau voor de Statistiek* (CBS, central bureau of statistics) and a report of the ministry of housing showed that calcium silicate stone was the cheapest. It was their calculation of square meter prices that led to the K-400 project. At a press conference CVK and the *Nederlands Christelijk Instituut voor de Volshuisvesting* (NCIV, Dutch Christian Institute for Public Housing)¹⁷ indicated that a house built in calcium silicate cost about 3,200, - guilders less than a house built in concrete. In 1993 an article in the journal *Bouw* (Construction) Van Deelen (1993:32) indicated that calcium silicate construction was institutionalized: “In house building the calcium silicate stone body belongs to the established order. Low price, high design freedom, simple realization and green image give it a competitive advantage over concrete”.

The question then is how calcium silicate stone arrived in this position. The short answer is by internal and external integration of the parties involved in its fabrication, implementation, and use. Internally, within the industry, calcium silicate producers traded the independence of individual producers for collaboration with competitors, realizing that this would better serve their collective interests. In 1990 CVK changed its legal status; formerly the central sales office for the calcium silicate became the Cooperative Society for Sales and Production of Calcium Silicate Stone Producers. This organizational form makes it possible for the industry to operate as an economic entity; it is now a holding that treats its associated factories as business units. In addition to CVK, there exists an *Vereeniging van Nederlanse Kalkzandsteenfabrikanten* (VNK,

Association of Dutch Calcium Silicate Producers), which represents the industry in contacts with the government in, for example, collective labor agreement negotiations or in the development of national and international standards. In 1991 the European CalciumSilicates Products Association (ECSPA) was established, marking the beginning of the European integration of the industry.

Externally, in relations with their direct customers, but also in contacts with various other actors in construction industry, CVK and VNK participate in commissions and project groups related to standardization, such as the working group Radiation Protection; the project group Building Decree; and the working group Acoustic Insulation. Furthermore, in 1993 the calcium silicate industry together with the brick and the cell concrete industry established a special chair in Masonry at the University of Eindhoven. The focus of the chair is on materials science and masonry mechanics. This chair was considered necessary to put masonry on the agenda, as academic structural engineering was and still is predominantly focussed on concrete and steel construction.

DISCUSSION

A comparison between the timber frame and calcium silicate stone sectors offers a view of the mechanics of technology transfer; it reveals similarities and differences between those sectors in the focus of their alignment efforts and in the tensions that motivated those efforts. Initially, both sectors' alignment activities centered on artifacts and technical features in order to improve their respective technologies. The timber frame sector worked on improving fire safety, damp protection, durability, thermal and acoustic insulation, and quality of the production process. Similarly, the calcium silicate sector tried to improve the physical performance and production of the calcium silicate stone and further developed its product range. But unlike the timber frame sector the calcium silicate sector went a step further by focussing on functional requirements that filtered into the industry from the outside. In order to meet the needs of small and medium sized construction firms the sector tried to improve its product and its construction practices. Thus its focus shifted from technical and physical performance to development of construction calculation methods and improving construction efficiency at the building

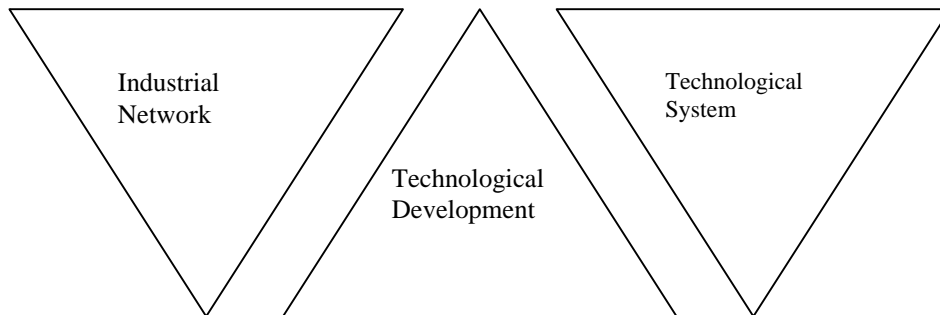
site. And while the timber frame sector continued mainly to interact within its own sector – timber frame producers, constructors, and architects – the calcium silicate sector extended its network and made the building site into a locus for aligning form and function. The calcium silicate sector worked on external and internal alignments alike, while the timber sector mainly focussed on internal alignment. In the one instance where the timber frame sector *did* try to build external alignment, namely in its effort to attune to societal needs for sustainability and user-friendly building, it did not succeed.

An examination of the tensions that drove alignment in the timber frame and calcium silicate sectors shows obvious parallels – and also striking differences. In 1947 the calcium silicate sector's main concern was to handle over-capacity and to prevent excessive competition. It solved this socio-technical tension through developing an assortment that addressed both the technical properties of calcium silicate stone and the consumers' (and hence producers') interest in products that would allow for variety in construction. While initially calcium silicate stone construction fitted in the brick regime, over time it developed a more diversified regime of its own. The initial familiarity of the players in the construction network with calcium silicate stone made its appropriation easier. On the other hand, the main tension for the timber frame sector related to the fact that on-site construction activities such as traditional craftsmanship, but also concrete construction, fundamentally differs from timber frame factory-based design and manufacture requiring only assembly at the construction site. This tension has not yet been completely solved and thus the timber frame method is mainly applied in niche markets for constructing privately owned houses, for specialties such as bent walls and roofs, and for creating form variance. The additional requirement of sustainability does not put much tension on calcium silicate stone because although it is less sustainable than timber frame it still is much more sustainable than concrete.

This comparison suggests that socio-technical alignment activities drive technology transfer. Alignment can be located at different levels, and for successful technology transfer internal and external alignments are necessary. The case studies show that alignment involves not only user selection of design alternatives – in fact, as it turns out, in both cases end users have very little say in the selection process. Rather, it

involves close cooperation over years between users, producers, developers, and builders. Consequently, technology transfer is an incremental process and it is easier to accomplish if some alignment already exists. Technology transfer will be more successful if the new technology relates to existing industrial networks and technical systems. The cases presented here indicate that socio-technical alignment should include both the network of players and the larger technical system of which a new technology is a sub-system. Van der Poel's triangle, then, is too simple a representation of the function form alignment. Rather than a hierarchic buildup of levels of relationships that captures the development of a construction regime, it is more useful to envision a tangle of relationships to represent only the network that is in play. But to keep some order in those relationships, let me suggest adding two triangles to Van der Poel's model – one at the form side representing the increasing complexity of the larger technical system, and one at the function side representing the increasing complexity of the larger industrial network (as in figure 4).

Figure 4: The function form trapezium



EPILOGUE: SEDUCING THE DISBELIEVERS

Instead of preaching to the converted, the CVK worked hard to seduce those who thought that the white calcium silicate stone was inferior to the 'red brick', and those who thought that it was impossible to make multi storey buildings with the white stone. In the nineteen eighties CVK organized instruction days for building firms. CVK's sales and marketing department brought the whole calcium silicate retinue along to all large Dutch conference halls. An invitation for one of the instruction days claims: 'You might think that it is

impossible but within an hour this wall is built'. Demonstrations and information showed how to use calcium silicate products. In 1993 the approach changed no longer a retinue through the country but twice a year three weeks of demonstration in a tent at one of the factory premises. In a five hundred square metres tent the technical people from CVK built a demonstration house showing details of how to combine and use different materials, such as concrete floors and steel supporting beams, with calcium silicate elements. According to Ton van der Kaats, staff member of CVK's construction technical department: 'Of course we want to sell our product but not by just making eyes at our potential customers, but by showing how calcium silicate can be part of a larger construction system. In the demonstration house, we show the new technical details and, moreover, suppliers of concrete floors, wall ties, and other supporting material have stands at the Demo Days. In those three weeks we have around 1500 visitors. From 3.00 to 8.00 p.m. we have special lectures for construction firms, while in the morning from 10.00 to 12.00 a.m. we have a program for architects, housing associations, the women's advice center and construction engineers.' Besides the Demo Days, CVK gives free instruction at construction sites, provides free construction calculations and teaches about the calcium silicate construction method at technical colleges. Clearly, over the years, the alignment of the technical properties of calcium silicate products with the functional needs of different users involved a seduction of the disbelievers through substantial interaction with all the parties.

NOTES

1. Names in this prologue are invented.
2. All translations from Dutch into English are the author's.
3. Pavitt (1984) developed a taxonomy of different types of firms, defined according to whether they are supplier-dominated, production-intensive, or science-based in relation to their capabilities to develop and use new technologies. According to Pavitt the innovation pattern in the construction industry is supplier driven. Other studies in the construction industry confirm this view (Pries 1995; Gann 2000).

4. Following Sarah Slaughter (1993) I use the term user-builders in order to make a distinction between end-users of buildings and construction firms who use construction technology.
5. This public housing sector in the Netherlands is large in comparison with other European countries; in the former West-Germany it is 16%, in France 17%, in the UK 24%, in Denmark 17%, and in Belgium 7% (Boelhouwer & Van der Heijden 1992).
6. In table 1 percentage of “other material” mainly includes the use of steel frames in commercial and industrial building.
7. For example the assembling construction method of *Bouwfonds Nederlandse Gemeente*, (Construction fund Dutch municipalities) (Priemus & Elk 1970).
8. This approach to socio-technical change is based on both theoretical and empirical findings from management approaches that see technology in its societal context (cf. Rip 1995; Rip & Kemp 1998) and from the industrial network approach (Hakansson & Snehota 1995; Von Raesfeld Meijer 1997).
9. Function is both what makers *inscribe* and what users *ascribe* to the technology, while form *is* what makers provide, of which the users choose and modify the functions they like. In Latour’s and Callon’s terms, the user is “inscribed” to varying degrees in the technology; one could argue that technology transfer depends on the degree to which. This inscribing of the user (and her demands) could be called an alignment process.
10. Compare for example with Clark & Fujimoto’s (1991) concept of internal product integrity referring to the consistency between the technical function and structure of a product, e.g. parts fit well, components match and work together..
11. Compare for example with Clark & Fujimoto’s (1991) concept of external product integrity referring to how well a product’s function, structure and semantics fit with customers’ objectives, values, production system and use pattern.
12. Over the years the timber frame demonstration projects reflect this shift in alignment focus. For illustrations see Banga and De Groot 2000; Meyer 1997; D Graaf 1996; Gordijn 1996; De Groot 1995; Vissers 1983; De Vlieger 1980.
13. Lately, an important issue because of stricter European anti-trust law.

14. The Building Decree forms a part of the Dutch housing law. The Building Decree formulates construction and housing technical performance requirements. Requirements relate to usefulness, health, safety and energy-efficiency.

15. In the Netherlands this situation is changing because of the high production and low availability of craftsmen. Gradually more prefabrication is used also by small and medium sized construction firms.

16. Renting such a house under the K-400 program would have cost about 400 guilders per month, which at the time amounted to about US\$ 200.

17. Historically The Netherlands was *verzuild* (compartmentalized) along socio-political lines. Public housing, but also health care, education, broadcasting and sporting clubs were organized around separate Catholic, Protestant, Socialist 'pillars'. Nowadays, there are still relicts of compartmentalization visible, but overtime boundaries blurred.

REFERENCES

Abernathy, W.J. and Utterback, J. (1978). Patterns of industrial innovation. *Technology Review* 50, 41-47.

Banga, J. and Groot, H. de (2000a). *Houtskeletbouw in Nederland: Een volwassen bouwmethode*. Rotterdam: Stichting Bouwresearch.

Banga, J. and Groot, H. de (2000b). *Handboek Houtskeletbouw*. Rotterdam: Stichting Bouwresearch.

Bijker, W.E., Hughes, T.P. and Pinch, T.J. (Eds.) (1987). *The social construction of technological systems: New directions in the sociology and history of technology*. Cambridge: MIT Press.

Boelhouwer, P. and Heijden, H. van der (1992). *Vergelijkende studie naar volkshuisvestingssystemen in Europa. Algemeen beleidskader*. Den Haag: Ministerie

Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer.

Breggen, M.W. van der (1999). *Bouwmethodiek en bouwkosten: project vergelijkende studie houtskeletbouw / gietbouw / kalkzandsteenbouw meerlaags appartement complex Chrysantenstraat te Aalsmeer*. Alphen a/d Rijn: Van der Breggen Architecten

Burgelman, R. (1983). A process model of internal corporate venturing in the diversified major firm. *Administrative Sciences Quarterly*, 28 223-244.

Centrum Hout (1999). *Annual report 1998*. Almere: Author.

Clark, K.B. (1985). The interaction of design hierarchies and market concepts in technological evolution. *Research Policy*, 14, 235-251.

Clark, K. and Fujimoto, T. (1991). *Product Development Performance*. Boston: Harvard Business School Press.

Clegg, S.R., C. Hardy, and W.R. Nord (Eds.) (1996). *Handbook of Organization Studies*. London: Sage.

CVK Kalkzandsteen (1996). *CVK geluidverwerking: het bouwbesluit en constructies in kalkzandsteen*. Hilversum: Author.

CVK Kalkzandsteen (2000). *CVK lijmblokken en vellingblokken: verwerking, assortiment en toepassingen van lijm- en vellingblokken van kalkzandsteen*. Hilversum: Author.

Deelen, P. van (1993). Casco van kalkzandsteen wint terrein. *Bouw*, 11, 32-36.

Deuten, J.J., A.Rip, and J. Jelsma (1997). Societal Embedding and Product Creation Management. *Technology Analysis & Strategic Management*. 9, 2, 131-148.

Dougherty, D. (1996). Organizing for Innovation. Clegg, S.R., C. Hardy, and W.R. Nord (Eds.) *Handbook of Organization Studies*. London: Sage.

Dubbeling, D. (2000). Houtskeletbouw goedkoper dan andere technieken: besparing kosten en energie. *Bouwmarkt*, 3, 6-7.

Gann, D. M. (2000). *Building innovation: complex constructs in a changing world*. London: Thomas Telford.

Gordijn, W. (1996). *Houtskeletbouw torenhoog favoriet: woningbouwproject te Delft*. Almere: Centrum Hout.

Graaf, P. de (1999), *Houtskeletbouw: handleiding voor de praktijk* Almere: Centrum Hout.

Groot, F. de (1995), *Houtskeletbouw in stadsvernieuwing: vier voorbeeldprojecten te Amsterdam*. Almere: Centrum Hout.

Groot, H. de (1999). Van Aalsmeer de victorie: meerlaagse houtskeletbouw verdient een bloemetje. *Het Houtblad*, (8), 14-19.

Groot, H. de (2000). *Meerlaagse houtskeletbouw Aalsmeer*. Almere: Centrum Hout.

Hakansson, H. and Snehota, I., eds. (1995). *Developing relationships in business networks*. London: Routledge London.

Hippel, E. von (1986). Lead users: a source of novel product concepts. *Management Science*, 32 791-805.

Hügli Pollock Read Industriële Marketing B.V. (1999). Rapportage: analyse relatieve marktpositie hout binnen een aantal PMC's, in Novem, *Monitor van de actie 20% meer hout in de bouw*. Utrecht: Novem.

Kats, P. (2000). Houtskeletbouw gezien door de ogen van de opdrachtgever. Proceedings Houskeletbouwdag 2000 Centrum Hout.

Klein, A. (1960). *Bouwen in kalkzandsteen*. Eefde: Vereniging van Nederlandse Kalkzandsteenproducten.

Leonard-Barton, D. (1991). Inanimate integrators: a block of wood speaks. *Design Management Journal*, 2 61-67.

Meyer, T. (1997), *Duurzaam en energiezuinig wonen: houtskeletbouwproject Zutphen*. Almere: Centrum Hout.

Milieuberaad Bouw (1995). *Brochure 20% meer hout in de bouw: actieplan*. Utrecht: Author.

Pavitt, K. (1984). Sectoral Patterns of Technical Change; Towards a Taxonomy and a Theory. *Research Policy*, 13 (6), 343-373.

Pinch, T.J. and W. E. Bijker. 1987. The social construction of facts and artifacts: Or how the sociology of science and the sociologie of technology might benefit each other. In Bijker, W.E., Hughes, T.P. and Pinch, T.J. (Eds.) *The social construction of technological systems: New directions in the sociology and history of technology*. Cambridge: MIT

Poel, I. van de (1998). *Changing Technologies*. PhD thesis Enschede: Twente University.

Priemus, H. and Elk, R.S.F.J. van (1970). *Niet-traditionele woningbouwmethoden in Nederland*. Delft: Research-instituut voor de Woningbouw and Stichting Bouwresearch.

Priemus, H., Bueren, E. van, Blaauw, K., Hasselaar, E., Klunder, G. and Veentjer, M. (1999). *Institutionele belemmeringen voor factor 20 bij besluitvorming over duurzaam bouwen*. Delft: Onderzoeksinstituut OTB.

Pries, F. (1995). *Innovatie in de bouwnijverheid: innovation in the construction industry*. PhD thesis. Rotterdam: Erasmus Universiteit Rotterdam.

Raesfeld Meijer, A. von (1997). *Technological cooperation in networks: a socio-cognitive approach*. PhD thesis. Enschede: Universiteit Twente.

Rip, A. (1995). Introduction of new technologie: making use of recent insights from sociology and economics of technology. *Technology analysis & Strategic management*, 7 (4), 417-431.

Rip, A. and Kemp, R. (1998). Technological change, in: Rayner, S. and Malone, E.L., eds. *Human choice and climate change*, 2 327-399.

Rip, A. (1999). A technology-in-society perspective. in Dolfsma, W., Geels, F., Kemp, R., Moors, E. and Rip, A. *Management of Technology Responses to the Climate Change Challenge*. Enschede: University of Twente.

Schuyt, J. (1999), *Timber frame construction: a critical assessment*. in Kuilen, J-W.G. van de and Linden, M.L.R. van der, eds. (1999), *Proceedings of workshop on design, production and building process of timber frame housing*. Delft: University of Technology.

Slaughter, S. (1993). Innovation and learning during implementation: a comparison of user and manufacturer innovations. *Research Policy*, 22 (1), 81-95.

Ultée, H.A.M. (1997), *De kleur van wit: de geschiedenis van CVK Kalkzandsteen*
Hilversum: CVK Kalkzandsteen.

Vissers M. (1983). Woningscheidende vloer in hbs vraagt veel aandacht. *Bouwwereld*, 79 (17), 18-22.

Vlieger, B. de (1980). *Houtskeletbouw: Een bouwmethode met specifieke mogelijkheden*. (Dokumentatie Bouwtechniek, Faculteit Bouwkunde, Vakgebied Bouwmethodiek). Delft: TU Delft.

Vreeze, N. de (1993). *Woningbouw, inspiratie en ambities: kwantitatieve grondslagen van de sociale woningbouw in Nederland*. Almere: Nationale Woningraad.

Vries, K. de (1999). Zweden aan de Schie. *Het Houtblad*, 11 (4), 14-17.