

# INTEGRATED PRODUCTION APPLIED TO THE BUILDING PROCESS

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## **Abstract**

Over recent years, manufacturing industries have become more and more integrated with their suppliers in their development and manufacturing of products. The whole supply chain is often seen as one integrated operation, and product development is the result of close co-operation based upon long-term agreements.

Toyota by the Toyota Manufacturing Principle was one of the originators of this integration, which today is widespread over all branches of the manufacturing industry.

Under an ongoing Danish development program for the Product and Process Development within the Building Industry, the methods from a recent Danish program for the integrated manufacturing have been applied to the building industry. The target has been the design and construction of social housing in the form of terraced houses and apartments blocks of two or three levels, but the system is suited for the construction of houses for disabled and elderly people as well.

A consortium of architects, engineers and manufacturers has devised a system where the building is divided into systems in stead of trades. Through a close co-operation with already existing suppliers, based on long-term agreements, these systems are developed to fit a wide variety of architectural designs.

The actual construction job is divided between the systems suppliers, who each have the responsibility for their detailed design, manufacturing and erection on site, all under the umbrella of the over all architectural design.

The first projects fully based upon these principles are well under way in the autumn 1998.

This new approach to the building process holds significant advantages compared with the traditional one. Not only in terms of a more efficient production, but also through stronger feed back loops improving the productivity as well as the product quality. Also a reduction of waste and a significant shorter construction time is foreseen.

The reorganisation does not take place automatically. At the supply-side it has to be supported by a continuous focus on how to improve co-ordination between companies, maintain a pressure for cost-reducing activities within the partnership and change the traditional mistrust into trust. Also the demand-side is at present badly shaped for a building market based upon the principles of integrated manufacturing. However, the main barrier seems to be the framework of formal and informal rules and regulations surrounding the building industry.

**Keywords:** Integrated production; Re-engineering; Building industry; Partnering.

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## **INTRODUCTION**

Over recent years, manufacturing industries have become more and more integrated with their suppliers in developing and manufacturing products. The whole supply chain is often seen as an integrated operation characterised by close co-operation based upon long-term agreements.

This development has not yet been the case in the building sector, which still consider each job a new undertaking to be performed by a team, selected for the job by the lowest tenders. However, under a recent Danish development program, a complete new approach to the organisation of the building process based on the manufacturing industry principles has been implemented. Section 2 outlines the principles of the integrated production system, section 3 analyses the building sector by the principles of the integrated production, and section 4 describes how these principles are applied in a specific case. A discussion of this approach to the re-engineering of the building sector concludes the paper.

## **INTEGRATED PRODUCTION**

The term Integrated Production has been coined through a Danish nine-year development program: Integrated Manufacturing Systems, undertaken by researchers within manufacturing and product development at the technical universities in Copenhagen and Aalborg, Denmark, co-operating with a number of companies within the mechanical industry (Riis 1996).

The program objective was to reach a new and broader understanding of the integration between industrial enterprises, and to develop methods to utilise industrial co-operation.

### **Expansion along the chains of business**

It is of great importance within the manufacturing industry to maintain the capability of fast reaction to changes. Consequently, production can not be viewed as an independent activity, but must be perceived as a number of chains in which the production is one chain only. Other chains are materials flow, order sequence and the product development process.

The flow of materials from the suppliers through the supply chains towards manufacturing, assembly, distribution, sale, delivery and commissioning must be integrated f.i. by means of just-in-time logistics. This brings new tools based upon information technology into play, and new ways of collaboration are established, just as new models for the organisation turn up, based upon mutual confidence and commercial integration. New roles for the employees and broader use of their competence come to the surface.

The product development processes change as well. Integrated design systems for retrieval and re-configuration of existing solutions combined with common systems for order processing and production planning, tie the parties in the supply chain close together. Integration is another consequence of looking upon the end products as product families with a diversification to suit the markets but based on modules. This approach reduces the complexity and supports repetition.

### **Integration**

Fast response to market changes calls for integration within the company, removal of internal boarder lines and local conflicts of interest, just as sub-optimising must be avoided.

Integration along the materials supply chain may have lead-time, process time and costs as guiding parameters. The processes are – in a development perspective – the starting points for a continuous improvement, as well as a more innovative stepwise development. Integration calls for a new understanding of their role by the employees, and development of new competence based upon a broader understanding of the whole process. In some industries a new understanding of foreign languages and cultures may be part of this integration as well.

A special challenge is to establish the integrated learning, which step by step increases the employees' understanding of the integrated competence.

### **Intelligent Production**

Usually the term Intelligent Production is interpreted as the use of information technology within the manufacturing processes. But the term can also be understood in the meaning maximum use of the human intelligence, creativity and imagination.

A surprisingly large number of industrial processes are still crafts. A number of activities within construction, purchase, planning, maintenance and quality control, as well as some parts of the manufacturing process, are still so dependent upon the human operator that fulfilment of time, quality and cost requirements is next to impossible.

The use of information technology pulls towards an industrialisation of engineering activities. In this, the manufacturing industry draws closer to the knowledge industry and will soon recognise that effective engineering may be the primary challenge for the engineer of the future. However, this industrialisation does not necessarily bring us creativity and intelligence. The IT systems must remove the boring and unproductive mental processes, release new potentials, and – not least – support the organisational learning.

### **Employee involvement**

The new challenges to the enterprise cannot be met without a new understanding of the role of the employees and their function. The need for the manufacturing industry is to create a prosperous co-operation in the essential matters of the company, making the employee understand, identify himself with, and participate in the realisation of the new goals presented above.

Core issues are engagement, motivation, and development of competence and involvement in the day to day processes as well as in the ongoing renewal of the business. Decentralising and mutual learning are of utmost importance.

## **THE BUILDING SECTOR IN THE PERSPECTIVE OF INTEGRATED PRODUCTION**

### **A Danish case study**

I 1998 the Danish Academy for the Technical Sciences initiated a study of the use of the integrated production principles within the building industry (ATV 1999). Not surprisingly, the study revealed a great difference between the manufacturing and the building industries, but it was also found that use of the integrated production principle, adjusted to suite the building sector's particular product, might be beneficial.

The study comprised a theoretical part, where the principles were applied to the building process and weaknesses in the process identified, as well as a study of Habitat, a consortium formed under an ongoing governmental programme for the development of the product and the processes within the building industry (EFS 1995). This consortium tries out an object oriented approach to the building process, dividing the operations into building parts instead of into trades, and relying to a great extent upon prefabrication.

### **Creating a filter for the building process**

Even though great generic differences exist between the manufacturing and the building processes, it may be useful to look upon the building industry through the spectacles of the manufacturing industry. Manufacturing has during the last decades shown a tremendous increase in productivity, a qualification the building sector still have to demonstrate. .

The filter to be extracted from their approach could be the four following aspects:

- **Organisation and co-operation**, where the manufacturing industry operates with an integration of strategies along the chains of business and with an integrated organisation characterised by a mutual confidence. The involvement of employees is stronger and their concern spreads out along the line of co-operation into the businesses of the partners.
- **Flow and logistics**, where the extended manufacturing system controls the flow of materials within and between the participants, and integrates the information and the use of IT across the boarder lines of the participating companies.
- **Design and product development**, where the integrated manufacturing re-uses designs and thereby reduces the complexity of the product, and takes the production process into consideration as an integrated part of the product design. Modulisation in the meaning modules that can be re-used again and again, is a very important part of the design process.
- **Processes**, where the integrated manufacturing operates with de-centralisation, co-ordination and continuous learning.

These four aspects will be applied to the building industry in the following.

### **The first observations**

Looking at the building industry with this in mind, attention is drawn to the fact that while the manufacturing industries generally are product oriented, the building industry is still process bound, as it was more than a thousand years ago. Indeed, the building industry is still organised to the rule: one skill equals one type of enterprise. The bricklayer in his kind of firm, the carpenter in his. Even the professionals: the architects and the engineers, tend to group with their own kind. This organisation does indeed give the customer access to a very flexible industry, but is probably at the same time the major cause of the low productivity and the unacceptably high amount of defects characterising the building process.

### **Organisation and co-operation**

The building sector is highly fragmented, and a large number of one-skill-only companies makes the entire sector look like a service industry. With a few exceptions, a new organisation is established for each job, and the selection of participants is based on the lowest bid only, not considering past performance at all.

Because of the sector structure the overall production responsibility is left with the client, even though he very seldom recognises this fact. But as all the participants put their skills only at his disposal and focus thereafter upon their own business, who else has the production responsibility?

Not only the participants, but also the organisation of the building process change from job to job, making it difficult for the individual to understand his role in the game. In consequence, each company considers the project one of a kind and the participating individuals consider their success within their own company to be more important than a successful completion of the project as a whole.

Furthermore, the contracts in the building process are mostly of a transactional type where the co-operation should be of a relational kind. This inevitably leads to disagreements and claims and not least to very high transaction costs.

Surprisingly, the rather complex building process is often characterised by a fairly weak project management. The reason that this does not lead to complete chaos seems to be the tradition for delegation of responsibility, combined with the high skills of the trained tradesmen. But the productivity is indeed influenced badly by the lack of planning and control.

### **Flow and Logistics**

The materials flow in the building sector is characterised by a high degree of randomness. Many materials are bought at the lowest purchasing price not considering the delivery service. This leads to deliveries not suited to the character of the building site and causes loss, breakage and pilfering. Other materials are bought as needed, i.e. being picked up at building markets the same morning as they are needed on the site, giving the building industry its own peculiar form of 'just in time' logistics. Storage costs or losses due to materials not available are obvious results of this kind of logistics. A number of Danish experiments have shown savings of up to 10 percent of the total constructions cost, when a systematic just-in-time logistic is applied to a typical building project (Bertelsen 1997).

Even with these experiences in view, and with easy-to-use tools at their disposal, Danish contractors seem very reluctant to introduce proper logistics in their operations. The sector apparently focuses on the cost of planning, not considering the savings gained later on. Maybe because the costs are carried in one part of the project organisation, whereas the savings show up in other parts.

Also the information logistics in the building process is random. Even though the design brief is prepared by means of modern information technology, the format is still like it used to be when the tools were T-ruler and triangle (Bertelsen 1992). The information is usually handed on in paper format, making digital reuse of the information next to impossible. Even though the very network nature of the project organisation should stimulate digital co-operation, IT is used inside each company only. The very transient nature of the co-operation in the building sector is probably one reason for this, but it may also be that the traditional division of all work into trades instead of into building parts, makes an object oriented approach in the IT systems very difficult.

### **Design and Product Development**

Each building project turns out a unique product as its final result. Even though the building is composed of standardised building materials, re-use of details in the design is not common. A systematic Danish effort over the last 25 years of standardising various details has given discouragingly insignificant results, even though the work was carried out with a heavy participation from the industry itself. One reason for this may be that the construction company in question is not known when the detailed design is decided, wherefore no incentive to reuse a solution already tried exists.

Indeed, not only the details are decided without respect for the construction process efficiency, the whole design is often made with the end result in mind only, not considering how it should be erected in an efficient way. Indeed, the word 'buildability' does not exist in the Danish language.

Only the manufacturers of building materials undertake a systematic product development. The architects and engineers make their development as an integral part of the design work, making each project a full-scale experiment.

### **Processes**

As in manufacturing, the building industry decentralises its processes to a very great extent, but does it in very old-fashioned way.

The lack of a common product, which can be subdivided into product parts, gives little basis for establishing firms specialised in their product. On the contrary, it makes most of the industry's enterprises multi-disciplinary in their product, but specialised in their trade. Most of them can produce anything within their trade and are doing so in quite a competitive way. Even so more and more specialist trades seem to come into play, making the process co-ordination more complicated. In Denmark a typical construction site often holds more than twenty trades where there were five or six only fifty years ago.

This great division of manufacturing responsibilities into processes makes the co-ordination effort very heavy, and a great proportion of the construction cost is related to transactions. A Swedish investigation into this showed that more than sixty percent of the worker's time on the construction site were spent on transactions and that almost one third of the total time was wasted completely (Hammarlund 1989).

Also common use of equipment such as scaffolding, cranes and vehicles is lower than optimal because co-ordinating is so complicated.

Some suppliers of building materials offer today to deliver their products in a prefabricated way, making them more and more being not materials only, but prefabricated building parts ready to assemble. However, traditions and outdated trade agreements inhibit these obvious opportunities to make the construction process more efficient.

As in any industry, the enterprises within the building industry experience continuous learning. But as every construction job is a different undertaking involving a new team of trade contractors, this learning is focused upon one's own experiences. Common learning and changes in common behaviour in order to make the whole undertaking more efficient is very seldom seen. To this should be added that costs of making the whole process more efficient must often be carried by a party who will not in the first hand get the benefits of the efforts.

## **HABITAT – A DANISH CASE**

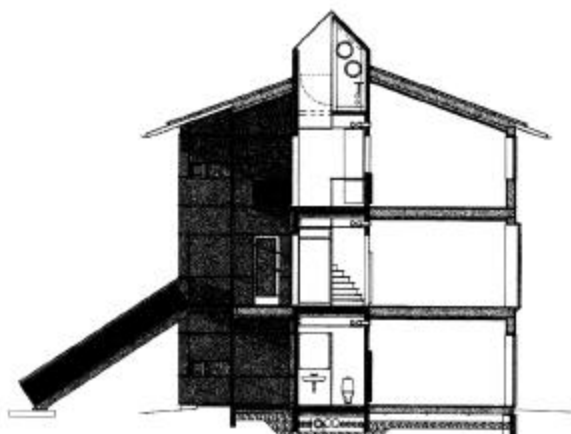
### **The Danish Process and Product Development Programme**

In 1994 the Danish Ministries for Trade and for Building jointly initiated the Product and Process Development within the Building Industry program (Clausen 1997, EFS 1995). Four consortia consisting each of at least a main contractor, an architect, a consulting engineer and a social housing association were selected to develop a new approach to the design and construction of social housing schemes.

Two of these consortia made their primary effort to apply industrial thinking and practices to the traditional building process, utilising tools such as supply chain management and just-in-time logistics. The other two consortia made the development of a new building system their primary effort.

### **The Habitat Approach**

One of these two product consortia – the Habitat group – did this in a very radical way. They started by considering the building as consisting of three subsystems only: the



building base, the 'wet rooms' i.e. the kitchen and the bathrooms which they named the 'Kernel' and the remaining part of the building comprising all the remaining rooms – the 'Wings', as shown in figure 1.

They recognised that even though the building base was to be constructed in a traditional way, the kernel and the wings might as well be based on prefabricated components, the kernel as room sized sections, and the wings as panelled elements. Instead of starting their own fabrication, the consortia established a partnering-like co-operation with already existing manufacturers of suitable products. The challenge of the consortia changed thereby from undertaking the whole building process themselves into an over all managing function. Their major role was now to organise the process and product development based upon existing manufacturing processes, to control the manufacturing and assembly processes, to establish the quality control system and to rethink the dialog with the customer and the end user, including the after sale service.

By doing so, their approach became similar to the one found in many modern manufacturing industries, working with a three-layer organisation of the manufacturing process.

At a recent meeting in the Danish Academy of Technical Sciences, Mr. Carl Erik Skjølstrup, vice president at the Lindø Shipyard presented their three layer model of the manufacturing process, shown in figure 2.

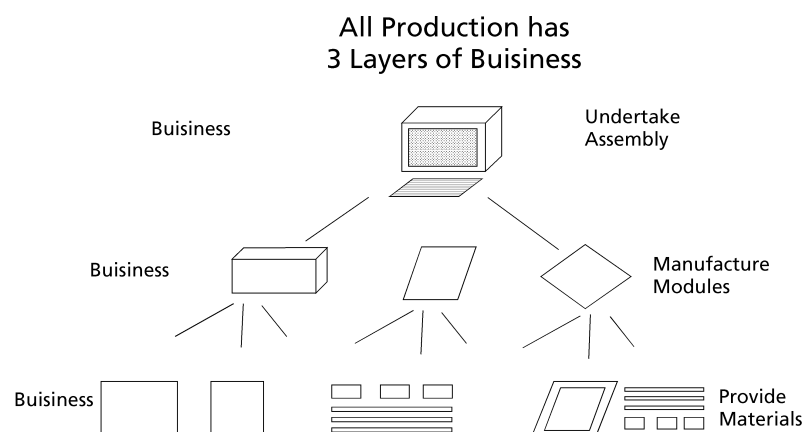


Figure 2. The Lindø Manufacturing Model

The upper layer is the assembly. Here the shipyard itself undertakes the job and ensures a product quality to the client's specifications. In the modules layer the partners manufacture their modules in accordance with the shipyard's specifications, but in this layer the partners also supply to other – maybe competing – shipyards. This situation ensures that their primary suppliers are competitive at the global marketplace, and that Lindø is not carrying all their

capacity costs. The bottom layer is materials supply where all participants are working at the global marketplace making them worldwide competitive.

### Habitat's Organisation and Co-operation

Habitat is organised as a limited company with the objective to develop and own the concept of organising the building process along the lines of the integrated production system. Habitat is not supposed to participate directly in the actual design and manufacturing processes, but to rely in this on its partners only.

The co-operation with the partners is based on long term agreements and the partnership consists of only a few of each kind of partner, the three manufacturers and the two designers: architect and engineer. The co-operation covers the development of the construction system as well as the actual deliveries for the projects. By this the partnership aims at optimising the operations at factory and construction site. Design for manufacture is a natural part of the development efforts.

The actual contracts for design and manufacture in each project are awarded to the partners best suited for the job in question.

### **Flow and Logistics**

The new way of dividing the construction process eases the logistics substantially. Almost all materials are now delivered to the plants where they are parts in a very controlled manufacturing, and the form of delivery can be arranged to suit the process in the best way. The flow from the plants to the construction site is characterised by the very few components, which are much easier to control. Also the components are delivered for instant assembly, avoiding nearly all storage at the site and thereby reducing breakage and pilfering considerably.

Furthermore, the long-term partnership stimulates a closer integration of the partners' IT systems, even though the new way of co-operating reduces the need for exchange of data compared to the traditional design and construction processes. But it is observed that the exchange of data between Habitat and the main suppliers and again between them and their materials supplier is undertaken in a very efficient way far exceeding the data exchange normally observed.

### **Design and Product Development**

The Habitat development process is characterised by the fact that the development takes place between the actual projects mainly. The design phase for a specific project therefore normally consists of specifying an assembly of already developed detailed solutions to fit the over all design by the architects. This approach opens up for a development process going far deeper into the problems than the usual design phase aiming at one of a kind solutions.

Design and specification of the individual project is undertaken in a workshop dialogue with the client, where the buildings in question are modelled in virtual reality by the architect, with the use of models of the system components. In this, the Habitat system has proven highly flexible being able to accommodate a wide variety of over all building designs.

Also, in spite of the greater efforts put into the development, the total costs of development and design seem to be lower than seen by the traditional approach. At the same time the design takes the manufacturing processes into consideration in quite a new way, giving further advantages by efficient production and assembly.

### **Processes**

Habitat has made a very consequent de-centralised approach to their re-engineering of the construction process. Their own role is to organise, manage and control the processes only and at the same time use the freedom gained hereby to focus on the customers' and end users' satisfaction with the product.

By this, the continuous learning so important in the manufacturing industry comes into play. The Habitat partners are certain that they will meet again in the next projects and therefore have a much greater incentive to learn from their experiences in the ongoing project or development effort. The continuous improvement of productivity as well as quality is an emergent feature in the Habitat approach.

## **DISCUSSION**

### **Improving the supply side performance**

As shown above, it is possible to organise the building process according to the principles of integrated manufacturing. However, this reorganisation is neither easy nor trivial. Three major barriers to the implementation of integrated manufacturing in the building industry can be identified.

The first barrier concerns the *co-operation* between the firms in the manufacturing process.

Besides industrialising, Habitat aims at a smooth running operation along the supply chains by separating the building into three different subsystems. Each subsystem is manufactured by existing manufacturers experienced in how to co-ordinate and ease their own production.

However, these manufacturers are not experienced in joint operations such as Habitat's, and consequently there is a strong need to co-ordinate their activities. Observations from the last Habitat-project shows that – in spite of a well-thought sub-division – co-ordination problems still arise when the dispositions of one manufacturer intervenes with the work of the others in unpredicted ways.

This task of co-ordination is well known from the traditional way of building, and the number of unforeseen events seems to be lower in Habitat's process. Probably, when gaining more experience, the Habitat consortium will know exactly how to address these problems. But at present the need for co-ordination causes irritation and potential delays because it is different to the ones, the parties are used to.

To overcome this barrier, the two-way strategy Habitat follows seems important. Firstly, to ease the tension between the manufactures. For instance by teambuilding, emphasising that processes should not be improved within the company only – the links between the companies also counts. Secondly, to speed up experience-based behaviour by closely monitoring and learning from ongoing building projects.

The second barrier concerns *trust*. Trust eases any kind of economic transaction, but is particularly important in organisations of the Habitat kind, i.e. close and long-term collaboration between economically independent firms. Trust, and mistrust, is based on the parties' previous experience. This makes it very hard to create trust within the building industry due to a long tradition of conflicts and short-term thinking. The importance of trust – and how to establish it – is discussed in detail in another paper at this conference (Thomassen 1999).

The third barrier is the *competition*, or rather the lack of competition within the consortium.

If Habitat turns out to be a success, the relation between the consortium and the partners will be more deeply rooted. This holds many advantages – e.g. low transaction costs and a high degree of learning – but may also be a pretext for doing nothing. At the beginning this will not be a problem as the participants' assignments are awarded in competition with other manufactures. But later on it will be hard to use traditional price competition because only the participating manufacturers know how to produce their particular part of the Habitat house. Also, at that time they will probably all be tied together by integrated information systems.

Consequently, it is important to maintain some of the incentives to reduce the costs. An obvious solution will be to benchmark the performance of each manufacturer over time. This makes it possible to agree upon an annual reduction of costs. Another possibility is to share information about the partners' earning and expenses. In this, the three-layer, Lindø-like organisation of the Habitat process becomes very useful because each partner bases his production on standard components with a well-known price.

### **Creating a demand side**

Even if the supply-side is not perfect, it is working. The main barrier to overcome therefore seems to be to create a demand side understanding and respecting a building market based upon the principles of integrated production.

This is a bit ironic. Usually, integrated manufacturing and business process re-engineering is seen as steps to fulfil market demand. This should also be the case in the building sector but without knowing it, the clients often hamper this development.

Habitat tries to establish a new relation with the client. But Habitat also expects the clients to perceive the house as a product designed according to his own demands, specified by himself at an early date. This is a very different approach too the present practice, where the client and his professionals intervene in all phases of the building process, a practice that doesn't respect design for manufacture. It is therefore necessary to change the behaviour of the client and his professionals. Many clients seems reluctant at such a change – maybe due to bad experiences

from turnkey contracts, where the client gives up his influence without having proper tools for defining quality of the final product.

There seems to be a great need for success-stories in order to ease the client attitude towards an industrial production, where changes after the design phase are next to impossible and extremely expensive.

Lack of competition between Habitat and other vendors is another problem in creating a demand side. Many clients are not experienced buyers. Since it is difficult to appraise a single proposal, these clients put their faith in competition by always choosing the lowest bid. In order to make the Habitat idea trustworthy, competition should not be avoided, but established on a new set of rules making it possible to compete on quality and past performance, as well as on price.

### **Providing the framework**

The building process is highly complex. The reason for it not ending up in total chaos is probably the frameworks guiding the process and thereby making it less complex in practice.

Talking about frameworks, we do not mean only legal and technical rules. We also think of mental, cultural and habitational structures that guide us through incalculable possibilities and problems.

These frameworks have emerged as the product of a long history where we learnt from experience and – often without knowing it – changed our behaviour accordingly. In stable periods, this framework is very beneficial. Actually, we could not live without it. But in re-engineering it causes problems, because the process no longer corresponds with the problems the old frameworks reflect.

We do not, and are not supposed to, think of these guiding structures in our daily routines. Actually, we only discover them when we try to change them. This is the process that Habitat is going through at the moment. In other words, we are just about to understand the shape and magnitude of the frameworks in which the building project is embedded. This is an area that needs more research, but let us outline what is emerging.

It would be obvious to point at the *legal framework*. One important aspect of the Habitat idea is that it allows competition on past performance and not only on quality and price. However, the tender regulations in Denmark and EEC are created in order to ensure price competition mainly. This makes it hard to replace one-off price competition with long-term relations based on collaboration. Also the rules for arbitration and for the correction of defects reflect the traditional trade based building process.

*Administrative procedures* are another framework that seems to be in conflict with the Habitat idea, f.i. the rules guiding social housing projects in Denmark.

Also the piece rate system hinders a re-organisation of the building industry. Firstly because the rates are based on previous experience. When doing things in a new way, none of the parties know how high, or how low, the rates should be. Secondly, piece rate payments are based on the idea of specialisation – i.e. the work is divided into clearly distinct operations. Integrated manufacturing changes this approach thereby making the piece rate system useless.

However, the main barrier seems to be *the way we think*. For instance, clients are so used to interfering in the building process that they find it hard to accept that they are buying a product and not a process. Correspondingly, experience from another – not yet reported – Danish innovation programme shows that the sub-contractors do not grasp the possibilities of affecting their building process. They are so used to a situation where the final responsibility for the detailed design and for the process organisation belongs to the professionals.

Going from tough price competition between trades to long-term co-operation between manufacturers requires a complete new way of thinking throughout the industry. Even if all the participants are aware that they are in a partnership, it is very tempting to the individual to give some assignments to outsiders that appears to offer lower prices. Such behaviour completely

ignores the benefits of the partnership, but seems logical from the traditional price competition framework's point of view.

But maybe the worst thing is not the magnitude of the frameworks but the need for *changing them all simultaneously*. If just one of the frameworks is still there, the new system will become dysfunctional, and the logical strategy from the individual party's point of view will be to go back to the old well-known ways, making the whole effort of re-engineering futile.

## References

- Akademiet for de tekniske Videnskaber (1999): *Byggeriet i det 21. århundrede – industriel reorganisering af byggeprocessen*. ('The Building Industry in the 21th Century – Industrialised Re-organisation of the Building Process', In Danish with an English summary)
- Bertelsen, S. (1992): *Musens Mening – om bygningsprojektet*. ('The Mouse's Opinion – on the Building Design Brief', In Danish, English translation available from the author)
- Bertelsen, S. and Nielsen, J. (1997): *Just-In-Time Logistics in the Supply of Building Materials*, paper presented at 1st International Conference on Construction Industry Development Programme, Singapore 1997.
- Clausen, L. (1997): *The management of innovation – Lessons from a Danish development programme*, paper presented at 1st International Conference on Construction Industry Development Programme, Singapore 1997.
- Erhvervsfremmestyrelsen (1995): *Proces and product development in the building industry – a Danish development programme*
- Hammarlund, Y & Rydén, R (1989), *Effektivitetet i VVS-branschen, Arbetstidens utnyttjande*, (Effectivity in the Plumbing Industry – the Use of the Working Hours, in Swedish), Svenska Byggbranschens utvecklingsfond, Sweden.
- Riis, J.O. et al (1996): *Det udvidede produktionsbegreb – Løsningsmodeller, udfordringer og perspektiver*, ('Extended Production – Models for Solution, Challenges and Perspectives', in Danish), Industriens forlag, København.