

CHALLENGES FOR CUTTING-EDGE CONSTRUCTION

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ABSTRACT

Construction is still an activity where waste of resources of every kind is an important problem. Other economic activities are apparently more successful in being able to boost productivity and reduce waste in the production process by implementing a targeted production process redesign. Theoretical views and international comparison at the status of managerial and technological capabilities in construction can show another approach towards a more cutting edge construction (production) process.

Construction management research in Delft University could bring about a profile of the elements that can improve the overall level of productivity in the construction sector through Cutting Edge Construction Management. New types of cooperation and contracting are designed following the lines of sophisticated Supply Chain Management in a typical Continental (Dutch) business environment. Projects are to be engineered obeying the laws of an industrial dominated production environment. Cutting Edge Construction will make this feasible by restructuring the ways of cooperation between all the building partners involved and by optimization of supporting (ICT) communication and knowledge management systems. Also other improvements of the construction process have to be studied.

This paper will formulate recommendations to be given for the improvement of the production processes in construction and civil engineering into more Cutting Edge Construction of which society will benefit.

KEYWORDS

Construction Management, Production Management, Technological Capabilities in Construction.

1. INTRODUCTION

Not even seen in a detailed perspective it can be stated that construction is an economic activity that is far from having optimized its production capabilities. Whilst in the automotive industry production methods are stripped to the bare bones and very little is still left to improve during the production process, in construction there is still a lot to do in this respect. It is still a quite messy industry, wasting all kinds of resources, material, natural and human. Since society, economy or the client in person is not yet eager to be more critical in the way the production process in construction has to meet quality standards and its social and economic costs should be considerably lower, there really is not a drive to implement improvements. Improvements should therefore being proposed and later implemented by the industry itself. This paper will deal with a proposal for improvements, derived from an analysis of the current 'state of the art' of construction worldwide. The analysis can bring about some identification of fields of improvement and even some concrete proposals. The paper introduces the concept of Cutting Edge Construction.

Cutting Edge Construction is presented as a container concept for a couple of comprehensive tools to boost the level of productivity in construction.

2. IDENTIFICATION OF CONSTRUCTION 'REALMS'

Globally spoken, in the world five 'realms' of construction, or areas where construction is organized in a specific way, can be identified. In random order:

1. The Continental European construction world;
2. The Anglo-American construction world;
3. The East Asian-Japanese construction world;
4. The construction world in (former) countries with a guided economy and
5. The construction world in countries with a developing economy.

The distinction of five realms will help to identify five different types of 'cultures' in construction that will bring about another structure of the construction process, resulting in a clear to be recognized different set of success and failure factors in construction.

Each of these types can, by this comparison, display the specific own casting success or failure factors that can be considered as an improvement to be gained.

3. QUALITY ASPECTS EVALUATION OF CONSTRUCTION REALMS

To study the casting differences in the identified construction realms it is necessary to list a large number of quality aspects and to review them. In the following global QUASE chart the most important casting features are specified. The aspects are listed in an 'organized' random order, comparing some possible opposite aspects, or aspects that are closely connected. For each aspect a judgment in five 'steps', noted with five to one plus signs, is made, trying to show the distinctive difference amongst the aspects. Five plus signs indicate a strong presence, or effect of the aspect, one plus sign indicates weak ones.

Table 1: Global Quality Aspects Evaluation QUASE Chart of Construction Realms

Aspect:	Realm:	Cont. Eur.	Anglo-Am.	Asian-Jap.	Guid Econ.	Dev Econ.
Gross economic value - GNP		++++	+++++	++++	++	+
Centralized government		++	+++	++	+++++	++++
Level of construction legislation		+++++	++++	++++	++	+
Level availability physical infrastructure.		+++++	+++++	++++	++	+
Level of investment in construction		++++	+++++	++++	++	++
General level of technological developm.		++++	++++	++++	+++	+
Average level of professional education		+++++	+++++	++++	+++	+
Level of workers education in construct.		++++	++++	++++	+++++	+
Percentage of large companies		+++	++++	+++++	+++	+
Percentage of small companies		++++	+++	++	++	+++++
Existence of an informal sector		+	+	++	+++	+++++
Centralized commission		++	+	++	+++++	+++
Predominantly private commission		++++	+++++	+++	++	++
Level of technological dev. in construct.		+++++	+++++	+++++	++	+
Level of integration construction sector		+++	+++++	++++	++	+
Value added by capital in construction		+++++	+++++	+++++	++	+
Value added by personnel		+++	++	+++	+++++	+++++
Value added by equipment		++++	+++++	+++++	++	+
Availability of ICT infrastructure in cons.		++++	+++++	++++	++	+
Level of process safety		++++	+++++	++++	+	+
Waste production		++++	+++++	++++	+++++	+++

3. MAIN ASPECTS FOR IMPROVEMENT DERIVED FROM THE TABLE

3.1 Overall Quality of the Construction Product

Although in most countries the quality of the construction product seems to be secured, in particular in the developing world still a lot is left to achieve. Apart from the informal sector, which flourishes widely in the developing countries, construction in general is able to deliver a reasonable product quality. In terms of environmental quality the construction world and its clients just started a process of awareness, bringing about the first results (see 3.8). The technical quality is sufficient, although not often up-to-date. In most cases the client is still quite conservative in formulating the commission, which results in not boundaries exceeding technologies and concepts. In general the construction product meets its requirements in terms of soundness and durability. In this category something has to be said about the maintenance of the initial product quality. In most countries putting a building together is one thing, but keeping it in a reasonable state of maintenance is definitely something else. Where construction products are primarily considered as valuable assets in the economy and property developers and property investors play an important role the recognition of the importance of efforts to extend the term of live by proper technical and user maintenance, is well developed.

3.2 Level of Technological Development

Construction can hardly be considered as a technology pushing activity. On the contrary, construction is quite able to use technologies developed in other technological environments. This does not imply that construction technology is seldom being developed by the sector itself. Especially in more 'hard core' construction, like civil engineering, 'innovative behavior' is to be found. Most innovation in construction comes from the material suppliers. They hold most of the patents in the sector construction. In the more developed world a reasonable level of technological development is common, in the less developed world this reasonable level is more exception than rule. It is generally accepted that this difference should be bridged by solid investments in technology transfer [see also paper 103 "Technological Capabilities for Sustainable Construction" by Emilia L.C. van Egmond – de Wilde de Ligny and Roger A.F. Smook.].

3.3 Process Quality

Where product quality is considered as reasonable the process quality is more often considered weaker. Construction as an activity originates from ages back, when process quality was not yet considered as a casting quality. Starting with the period that industrialization of construction came about, it became apparent to the sector that a lot of money was to be gained by efforts to improve the construction process. In most of the mentioned construction realms the construction sector is still very much segregated. Process participants of lots of different backgrounds contribute to the construction sector. They share a predominant attitude. That is that they want to stress their professional integrity and independence, preventing them to more act as a solid 'pack' of individual professionals pursuing a common goal. For example: An architect is quite another 'animal' than a straightforward contractor, even so that the structure of the building process is designed to exploit this animosity. The architect on the same side as the client, but much more culturally educated - he is convinced of his superiority in this respect - and the contractor on the opposite side as the person trying to exclusively reaching for his financial goals, disregarding the client. Throughout the building process these antitheses can be recognized, resulting in considerable losses of quality and cutting edge performance. In the developing world this situation is of slightly different nature. Here the process partners are so different in quality of professional education and technical means, that cooperation is difficult by nature.

3.4 Level of Productivity in Construction

Where technological performance is reasonable and process performance is rather weak, for construction this contributes to a quite poor level of productivity. Admitted, that construction has to obey other production methods and rules than with industrial production, this alone cannot be the excuse for such a poor performance in comparison with the industry sector. Often the comparison is made between construction and the automotive industry to illustrate this point. In the 'pre-Ford' era cars were produced similar to what was common in construction. After the introduction of the assembly-line and the proper tuning of all supporting production systems and the later Japanese improvements in this field [see Womack et al] the automotive industry could dramatically lower the price per unit and improve the freedom of choice for the client in the same time. To such an extend that the construction world could never achieve. The major reason for this can be found in the earlier mentioned lack of cooperation between

the process participants. Where in the automotive industry co-makership is widely introduced and even became the standard in the supply chain, this is not the case with construction. Here the so-called 'purifying' distance between partners in the supply chain is still very much advocated. Each supplier is better squeezed with his price, than taken on board to contribute more, but not being sure he delivers for the lowest possible price. Generally spoken the overall level of productivity is not ideal in the Continental European realm, it considered being better in the Anglo-American realm. An explanation could be found in the phenomena of the Quantity Surveyor, who can as an intermediate person propose ways of better cooperation. Productivity of the in the table mentioned last two realms is considerable lower than elsewhere, mainly due to the poor technological standards in construction.

3.5 Segregation and Ways of Cooperation within the Construction Chain

The almost tormented way partners in construction are segregated and yet are destined to work together, need to be elucidated a little more. In contracting many ways of structuring the cooperation between partners are being established. The use of a Building Team or Design & Construct and Build, Operate and Transfer contracts try to best bridge the differences between partners by bringing the separate partners with their professional capabilities together under one contract. But even under the same contractual heading, faced with the same restrictions the contract does show signs of a 'Living Apart Together' relation. A real integration of activities cannot be achieved. 'Cultures' differ too much. This is the case in parts of the world where a higher level of professional training can be found. Partners in the building process are apparently trained in their own profession first, leaving to little space for proper training of capabilities of working together. In other economic activities the process partners are better trained on the job in in-company programs, following a different initial training. Since most partners in construction are not member of a same 'family', but only working together on project base, this form of close cooperation cannot be achieved. In developing countries the segregation is less dominant, due to the lower educational standards. Where building is a complete informal sector, of course these problems do not occur.

3.6 Availability and Use of Information Systems

Bringing different professional capabilities together requires a good functioning medium. ICT, Information and Communication Technology is still very much in juvenile state. Computers are widely used already in generating the necessary material in the earlier phases of the process. Pre-project research, the Program of Demands and most of the design, calculation and preparation is produced using computers and other ICT means. That does not mean that the construction sector could agree on one system to be used by all partners. In each stage of the process another system is dominant and can seldom be used in the next stage, or was used in the earlier one. So far the situation with neighboring professionals can be described. In the technical well-developed world this situation prevents the industry to really improve the processes. The use of the Internet as a world spanning Information Data Base has only just begun. The Internet can be made instrumental to transfer information to the projects, being independent from distances between the place of generation of the information and the place of consumption. In the less developed world there is still a huge backlog concerning availability of communication systems like reliable telephone and data connections. But even in the more privileged parts of the world the full possibilities offered by Internet are not yet used. Information provision through XML and PDM and similar computer techniques are not yet used to their full extends.

3.7 Quality of Work: Human Resource and Safety

In all parts of the world construction is still considered as a quite messy activity. Rates of mortal and 'normal' accidents with construction belong to the highest in economic activities. The not quite well developed and designed production process in construction is to blame. Here a specific role by the legislator is required. In many countries in the world the suitable attention for this human resource and safety aspect has only emerged recently. In the Anglo-American realm legal aspects like company liabilities are mostly very important. This gives this construction realm an advantage over all the other in implementing inherent safe procedures. Generally spoken there is a certain reverse interdependence between the technological development of the construction process and the quality of work for the workers involved in the process. The technological weakly developed construction process in developing countries brings about a very bad situation of the measures to secure a minimum level of safety on the job. On top of that the number of labor force is considerable higher than elsewhere. The economic losses that are caused by this will not be add particularly to the overall poor profitability of construction in these parts of the world. This is the reason for the poor profile of this aspect of construction.

3.8 Quality of the Construction Product: Technical and Environmental Quality

Construction is generally spoken also a quite messy activity in terms of environment protection. In the less developed world still a lot of environment polluting materials and production methods are being used. In the developed world environmental legislation is fighting back the amount of polluting materials and waste, but the sheer fact that construction production is considerable will spoil the positive influence. On top of this the high productivity is a threat in its own right. Dense populated urban areas requiring lots building push the bearing capacity of the natural physical environment to its limits, or even beyond.

4. EXPERIENCE WITH ASPECTS FOR IMPROVEMENT IN THE NETHERLANDS

4.1 Product Quality

In the Netherlands experience with enhancing the product quality of construction show clearly the limits in terms of economic feasibility. When product quality is over a certain satisfactory level extra emphasis on the quality is pushing the price that much, that in economic terms, the extra investment is no longer paying off. The main problem of focusing on product quality is in particular coming down on an extra involvement of the legislation. The 'amount' of product quality legislation can provide a secured level of quality in construction, but also has a price increasing aspect. On top of that product quality legislation only embraces the highest standards possible, something that is not necessary under all circumstances. In the Netherlands a tendency can be recognized that in particular in commercial construction projects the required 'life expectancy' of the buildings is put deliberately on a lower level than usual. There is a feeling that the economic lifecycle should not necessarily be exact congruent with the technical lifecycle. Construction products are gradually being considered as consumer products with a limited life. Recent studies in the Netherlands show that in housing the lifecycle of the product had come down from average 60 years to less than 30 years. A proposal to adjust the level of compulsory quality standards to the clients' requirements in this field is being studied.

4.2 Process Quality

In Dutch construction the average process quality is rather poor. This apparent noticeable level of non-fulfillment can be understood by the following:

1. The client is often the weakest link in the construction chain. He is permitted not to exact formulate his commission in an appropriate early stage. This brings about many alterations of the initial Program of Demands, resulting in the not cutting edge character of the production preparation phase of the project. In the same time it enables the contractor to reformulate the contract and to compensate possible losses on the initial contract. Resulting in a considerable price increase. Recent experiences in the Netherlands with large civil engineering projects show that this can cater for a price increase up to 300 percent. A project like the 'Betuwelijn', a 160 km long freight-train railway line between Rotterdam and Germany, was first planned to be build for \$ 1,6 billion, but is expected to cost over \$ 4,8 billion on completion. For a great deal this is caused by a poor performance of the central government in its role as commissioner of the project. This is shown in a recent report of the agency that controls the spending of the national budget.
2. The use of cutting edge planning techniques in construction is still rather poor. With contractors a special department 'preparation' does the initial planning of the project. As a result of poor communication between this preparation department and the responsible project manager, many construction projects have often to be planned over and over. Even with the help of sophisticated technology in ICT with advanced planning programs the traditional structures within construction companies are too tough to allow changes.
3. The design of the production process is most cases far from flawless. Several Dutch surveys indicate that through business redesign techniques between 8 and 15% could be gained in profits on operations and even more in respect to building time and savings on failure prevention. This quite alarming figure does not push companies to take actions for improvement. Despite of certain efforts by a limited number of companies, in this supported by building research institutions to eradicate failure in construction, little progress is made. Apparently the overall structure of management of all levels in construction is not keen enough to implement improvements in this field.
4. In the Netherlands most of the contracts between the client and the builder a still of a traditional nature. First experiments with contracts like Design & Construct only date back to 25 years. Anglo-American contracts like CM are hardly known in the Netherlands. The typical Dutch traditionalism often results in a not quite cutting edge way of structuring the project and through that in a rather poor process quality.

4.3 Cooperation within the Construction Chain

Since the process partners in construction in the Netherlands traditionally act quite separately, attempts to establish a closer cooperation are bound to fail. The client is operating on a too low level, the architect still considers his role in the building process as crucial although he is hardly providing the services he is entitled to provide and the contractor is too little client oriented and not willing to team up with the supplier. In short: the Dutch construction market is still very segregated, neglecting opportunities to improve performance by closely working together. The traditional relation between the architect and the contractor should not be an obstacle in improving performance if the game of the 'natural antithesis' is played well. A lot of process quality is to be gained with a close cooperation between contractor and supplier in the procurement phase by entering in forms of co-makership. The automotive industry should show the example of how this can be achieved [see Doenrade Report].

4.4 Availability and Use of Information Systems

In the Netherlands ICT is still poorly introduced in construction. Architects exclusively generate their designs with the help of computers and design programs like Autocad. With them and their 'aids' the structural engineers and the construction management consultants CAD is common. Not with contractors, who should use CAM programs in their production management. On the building site the computer is only used for design and administrative purposes and in some cases to structure logistics on the building site. Where a lot is to be gained is the use of ICT in the production process where more repetitive production can be executed by robots. On the other end the Internet should be used more in material supply. In the design phase still lots of catalogues of building materials and products are being used where in a well developed supply chain management forms of PDM in an XML environment can help to improve the access to an extended international building products market. The infrastructure is available, but no supplier is investing in this technology. In the Netherlands only preliminary studies are carried out in this field with poor involvement of the supply world.

4.5 Quality of Work

In construction in the Netherlands many legal compulsory systems to improve conditions for construction personnel are in force. Nevertheless the rate of accidents on the job is under the highest in production environments. Although legislation on safety regulations is rather strict and is reasonably well maintained, the average age of workers in construction is low. Work participation is well under 40% in the age category 50 to 55. Apparently construction is still a very health threatening activity. Only an ongoing industrialization of the production process in construction can help to improve this situation. In an industrialized production process the quality of work can be better secured than the in principle open air production we are used to in construction. Although there is a tendency to use more and larger or complicated components in construction the added value of this production method in construction is still quite moderate in the Netherlands.

5. INGREDIENTS FOR CUTTING EDGE CONSTRUCTION

5.1 General Direction and Implementation Policies

Cutting Edge Construction is a container concept for a couple of comprehensive tools to boost the level of productivity in construction. A selection of ingredients can help more than others to get to a reasonable level of Cutting Edge Construction. The ingredients are derived from the main aspects mentioned in the table in this paper. The most important ingredients are reported in a particular order, expressing the relative importance of the aspect.

5.2 Product Quality: Exploitation of Technological Capabilities

Most important in Cutting Edge Construction is how technological improvements of the construction process can be introduced in the production process. This requires a striving research environment (technology push) and a certain mentality to be focused on the introduction of novelties. On top of that the construction market should be receptive for aspects of modernization of construction. This is best achieved by having an open market that can 'reward' investment in new technologies (technology pull). The decisive factor in this is the attitude of the client. If the client is not insisting on being served with most advanced technologies the introduction of these technologies will stay behind.

5.3 Process Quality: From Cooperation to Co-makership

Construction will stay an activity that only can be done with a great variety of different contributors that must be managed to work together. For Cutting Edge Construction the different contributors or partners should no longer contribute in competition to the construction process, but should get organized in a long supply chain in that all partners take a kind of joint responsibilities towards the project. A shift from competition to co-makership can help very much to prevent failure costs and add to a more concurrent structure of the construction process.

5.4 Process Quality: Trimming and Re-designing the Process

In the average construction process, especially in the developed world, where many partners contribute to the process, the process design is often far from cutting edge. Still a great deal of effectiveness is lost by not pursuing business redesign techniques. In terms of failure prevention and process acceleration major improvements can be made. It requires an open-minded attitude and a willingness to adopt and to implement total quality management principles.

5.5 Process Quality: Imbedding in the Legislative System

The 'heavier' the legislative system is interfering in the construction process, the more difficult the process can be accelerated. In most cases the legislative system is granting licenses or building permits piecemeal, where a more concurrent granting can speed-up the construction process. When construction becomes more complicated, more legislation is added to the already existing resulting in a very complex legislative structure. Ideally from time to time the legislative structure need to be revised or redesigned in order to expunge unnecessary items. Of course this aspect is beyond reach of the construction industry and has to be carried out by national legislative authorities.

5.6 Quality of the Work Force and Quality of Work

Only by giving full attention to the worker in construction in re-engineering processes the quality of work can be improved. Improvements have to be found in better training, but also in a good engineered higher safety level on the building site and a better attitude towards the use of hazardous materials and tools in the construction process. Sufficient investments in the quality of the work force by general training and by specialized professional training on the job can help to boost profitability of the construction sector. Only partly this can be done by the industry itself: most has to be achieved by the national authorities on the part of general education. The technology status of a country is still of great importance for the results being achieved in construction.

5.7 Use of Information and Communication Technology

In the modern construction process a lot of the total quality is depending from a sufficient level of communication and information technology. The availability of communication systems in countries is vital and need to be catered for by the authorities. A lot has to be done by the industry itself. The whole construction chain has at least to adopt compatible information systems and agree on a lot of common applications. This counts for automated design systems with possibilities for all building partners to access. Even more important is the adoption of one automated calculation system for the whole production column from designer or architect, via the structural and cost engineer to the contractor and the material supplier.

5.8 Creativity, Flexibility and Societal and Cultural Conscience

Construction is too often an activity that seeks to copy earlier successful projects and to build in this way upon earlier acquired experience. This attitude kills creativity and flexibility and prevents to take each time a 'fresh' look at a new project. 'Continuous creativity' is the only 'vehicle' to the by society and client required constant improvement of the construction process. The creativity can be obtained by adopting a critical attitude towards realized projects and to study particularities of the construction process in other parts of the world. This item is particularly mentioned because generally spoken creativity and flexibility are not amongst the most predominant qualities of actors in construction. Since construction is culturally a very important activity, society may expect that construction be developed in a way society can benefit most.

6. CONCLUSIONS: GETTING AT CUTTING EDGE CONSTRUCTION

6.1 From Current Practice to Cutting Edge Practice

Many of the proposed improvements of the construction process are dealing with the establishment of technological systems, but require a shift in 'construction culture' in the same time. In the long run the technical aspects can be implemented worldwide. It is questionable if the more psychological aspects can be 'adopted' in the same time. Cultural changes tend to take more time to be implemented. Improvements cannot be implemented on too short notice. Therefore a certain sequence has to be indicated. Casting factor in this is the relative added value of the improvement. In the following proposal for a certain order the relative added value is suggested without being studied in detail. It is derived from experiences gained in the 'micro cosmos' of the Dutch construction world. Further studies are required to provide a reliable set of criteria to decide on the best order.

6.2 Sequence of Improvements

Under heading 5 a certain ranking of importance of improvement actions is given. Since aspects are so much interrelated, it could be helpful to try to suggest and to show a certain sequence in actions to best start the process of improvement implementation. Referring to several programs, being executed in the Netherlands the following sequence can be proposed:

1. Investment in general training and in professional training programs.
2. Introduction of co-makership initiatives in the construction chain.
3. Implementation of ICT systems in the complete construction chain.
4. Investment in new technological capabilities.
5. Introduction of business re-design initiatives within the construction companies.
6. Reduction of 'legislative load' of construction.

Depending upon certain characteristics in the different realms the preferred order can differ. Generally spoken the proposed sequence can be used as a starting point for further research needed to advance the cutting edge status of construction.

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