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Published in:
Proceedings of the First International Conference on Services Science and Innovation

Publication date:
2009

Document Version
Publisher's PDF, also known as Version of record

The Impact of Ict on Business Models for Delivery Of Consultancy Services – The Case Of Technical Engineering

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Abstract

This paper analyses the impact of the use of ICT in production and delivery of technical engineering consultancy services on business structures with regard to industry convergence and transaction costs. The paper takes an empirical study on the introduction of 3D-modelling tools in the building section in a Scandinavian engineering consultancy firm as its point of departure. The discussion identifies three different structural aspects, which all are affected by the use of ICT: Internationalisation vs. Local markets, Outsourcing vs. Structural integration, and Division of work between actors within the value chain

Keywords: industry convergence, engineering consultancy, value chain analysis, internationalization

1 Introduction

This paper analyses these challenges by use of a case study on the use of 3D models in production and delivery of technical engineering services in building construction. The paper focuses on three different structural aspects, which all are affected by the use of ICT and related to possible business models applied within technical engineering consultancy:

1. Internationalisation vs. Local markets
2. Outsourcing vs. Structural integration
3. Division of work between actors within the value chain

These structural aspects have all to do with the boundaries of the firm, which have been analysed by a number of theorists including [5] and [18]. They compare the relative advantages of hierarchical and market methods of organizing economic activity [11]. According to their analysis, the relative advantage of a hierarchical organisation is that coordination costs are lower than in a more market based structure, involving several partners e.g. through outsourcing of certain parts of the value chain. On the other hand a hierarchical organisation may increase production costs, as all processes are performed in-house – even if other companies are able to provide the same service at a lower cost. It can therefore be expected that sectors, where coordination costs are high compared to the costs of production will be more hierarchical in their organisation than industries where coordination costs are low.

The use of ICT based solutions in service and manufacturing industries provides an unforeseen flexibility in organisation of businesses both internally and externally, and at both national and international levels [6; 8; 10]. Business-to-business applications provide technical possibilities to co-ordinate business-functions across different locations and across different organisations. To accomplish the potential benefits, businesses have to reorganise in order to achieve the required flexibility and still reap large-scale benefits [12].

The use of ICT affects production costs as well as coordination costs, but since coordination in essence is about communication and processing of information, it is likely that especially coordination costs are affected (Malone et al, 1987). The use of ICT based solutions in service and manufacturing industries provides an unforeseen flexibility in organisation of businesses both internally and externally, and at both national and international levels [6; 8; 10]. Business-to-business applications provide technical possibilities to co-ordinate business-functions across different locations and across different organisations. To accomplish the potential benefits, businesses have to reorganise in order to achieve the required flexibility and still reap large-scale benefits [12].

An empirical study on outsourcing and offshoring of business services indicates that the organizational level of ICT use is positively correlated to use of outsourcing arrangements [1]. Malone et al mentions two other factors affected by the use of ICT with importance for the boundaries of the firm: Asset specificity and complexity of product description. According to Williamson [18] asset specificity relates to resources, which are highly specific to a physical or a human asset that cannot easily be used for other purposes. Acquiring these kinds of resources on a market will usually involve high coordination costs.

Coordination costs also relates to the complexity of product description. Selling and buying of a complex product demands more coordination than trading standard commodities. Especially when it comes to knowledge based service products which are difficult to codify, coordination costs may be substantial.

Carlile defines three distinct levels of knowledge processes[4]. The first level (knowledge transfer) is the basis of all forms of communication providing an ability to transfer knowledge from one part to the other through the use of different media and shared language. When unsettled ambiguities such as unclear differences or dependencies exist between the domains; a new type of knowledge processes named translation are needed. These processes aim at creating shared meanings or reconcile differences in meaning though processes such as externalization of knowledge. Shared methodologies such as CAD/CAM templates are mentioned as a concrete example of a tool to provide for knowledge translation. The use of ICT directly affects the level of knowledge transfer if shared methodologies, such as a common CAD/CAM templates is used to transfer and partly translate (codify) knowledge into a transferable format.

On the highest level of knowledge processes we find the need to negotiate differences of interest. This level is called transforming knowledge. Knowledge transformation might generate coordination costs to some of the participants. There may be a need to change either domain specific knowledge or collective knowledge to make room for innovations. Changing the knowledge acquired is costly it takes time to learn and it takes time to change the current knowledge integrated in practices and thus patterns of thinking. The process of negotiating differences is of course even more complicated in the case of inter-organizational collaboration where distinct economical issues are at stake.

This paper will use introduction of 3D models in technical engineering consulting within the area of building construction as a case for an analysis of the impact of ICT on company and industry structure in knowledge based service industries. Delivery of knowledge services involves knowledge sharing between producers and users. The information delivered in relation to building projects is often complex and requires interaction between several partners including managing knowledge across organizational boundaries.

In order to shed light on the structural aspects affected by ICT we first describe the working processes related to engineering consulting within the area of building construction. Second, examples of use of various ICT based applications supporting these processes are presented. Finally the implications for industry structures are discussed.

2 Method

The case study took place during 2005-2007 before the 3D system was fully implemented. We made 14 interviews of 10 different respondents including af follow up interview in 2008. The repsondents were placed in the company headquarter or in one of the regional offices. These respondents represented different levels in the management structure, from the CEO, to the IT-director and HR-director as well as department leaders and project managers involved in the daily work of projecting and designing. We presented the HR-director with a list of themes to address. These themes were eg. internationalization, innovation, knowledge management, productivity, working practice. He in turn selected respondents and asked them to participate. All interviews took place at the company site. The interviews were semi-structured; we followed an interview guide with a general section as well as a customized section based on the respondent's occupation and area of expertise. We included new questions along the way based on the information and insights gained in earlier interviews. This approach made it possible to stay open to new issues of interest as well as to go deeper into particularities. Apart from the dialogue, respondents demonstrated standards and systems in use to give us a more concrete understanding. Each interview, lasting 1-2½ hours, was either transcribed or reported extensively. All interviews were analyzed thematically: firstly through the use of the themes that guided the interviews; later through more detailed themes rising from the first round of analysis as well as themes growing out from the application of different theoretical lenses used to analyze the material. The role of technology and BIPS was recognized early leading to questions on the influence of BIPS as well as the use of technology to standardize and frame the work. Apart from the company specific material other materials regarding cooperation in the building sector was found and used. The BIPS website was visited and materials from here obtained. We also found other sources of interest such as reports and websites providing descriptions and perspectives on the situation, including evaluations of initiatives to support the building sector; the sources of this material was mainly governmental institutions.

3 The Building Section in Ramboll

Ramboll was chosen as case as the company is specialised in designing unique solutions for prestigious buildings, rather than in developing standard solutions used for mass production. Helping developing new production tools like 3D modelling systems, represents a special challenge to Ramboll as such tools may be acquired by Rambolls competitors on the market, which may then challenge Rambolls reputation as being among the most advanced with regard to technical expertise in building construction. However; the current approach here is also challenged using a standard-based tool. We have chosen to focus on the integration of 3D models as it highlights a wide range of possibilities and challenges within the organization as well as in inter-organizational collaboration. As will be discussed later 3D modelling both affects processes of coordination and production.

Ramboll is a leading player in the Danish market of technical engineering. In 2003 Ramboll and the Swedish engineering company Scandia Consult merged. Ramboll developed from being among the top three at the Danish market to become a leading player at the Nordic market with 104 offices in the Nordic region and 21 permanent offices in the rest of the world. The Ramboll group provides a broad range of engineering, consultancy services, product development and operation services within the areas of: Buildings, Infrastructure, Industrial processes, Energy, Water and environment, Telecommunication, Management and IT.

Ramboll group includes six different companies covering each of the Nordic countries; Denmark, Sweden, Norway, and Finland. In addition, Ramboll Informatics and Ramboll Management are defined as separate companies. 42% of the revenue is generated by Ramboll Denmark. At present, the national offices serve in general their own home-markets, but it is the intention to strengthen international co-ordination enabling collaboration in the provision of services across those companies being able to use special competencies in the entire Nordic region.

The building division in Copenhagen is organised according to technical disciplines such as steel constructions, concrete, electrical installations etc. The blend of geography and professional focus in the departments are seen to provide the best conditions for developing expert knowledge and educating experts. Locating people from the same professional area together gives them a daily contact with colleagues from the same discipline and facilitates further development of their competences. This happens, however, at the expense of the coordination between different fields and development of inter-disciplinarity within the projects. Other consultancy firms have chosen a structure, where offices are defined by market segmentation. In such a structure each office posses a broad range of technical expertise, and will be able to carry out many projects without consulting other parts of the organisation, however they face the challenge of keeping each employee updated within their field of expertise.

In Ramboll, it is thus necessary to involve several parts of the organisation in a project. Ramboll uses therefore a kind of matrix organisation. Most assignments are defined as projects and a project structure is operated across the line structure. Engineers can be allocated to several projects at the same time. When big and long lasting projects are running such as the Opera House in Copenhagen, many employees are allocated full time and a contemporary department, where project members are placed together during the project, is established.

4 Engineering Consulting in the Building Industry

The building industry has for decades been characterized by increasing costs, low productivity and often poor quality. This is in part due to labour intensive production processes in design, projection and construction, which have proved to be hard to automate. Another problem is lack of co-ordination between the large numbers of partners involved in the building projects. Knowledge flow between partners coming from different companies is often limited due to lack of common standards, lack of a common understanding on how the building process is organised, and the varying division of labour and responsibilities. This results in unnecessary conflicts and errors. In addition the lack of knowledge flow within building projects reduces accumulated learning both across partners and across projects. These problems are reinforced by the temporary character of partnerships, where different partners are collaborating on each project [7]. Moreover, the ongoing globalisation, taking place in segments of the building industry complicates co-ordination between partners even further along with a strengthening of the competition.

Use of ICT in the production process offers a number of advantages addressing these problems. In general the digitalization of data used in the design and projecting phases enables reuse of data both within the organisation and by collaborating partners. In addition the growth in inter organizational and intra organizational networks makes it easier to connect and exchange data and communicate on a more ongoing and direct basis across time and space within and between organisations. Furthermore the use of new ICT based production tools have enabled automation of the processes and thus led to reductions in the need for manpower, at the same time the content of the jobs have become more abstract as seen in other industries [19].

80% of the business in Ramboll's building section comes from so-called traditional projects of counselling and planning & projecting new and unique buildings. The assignments in the individual building project may vary in size but they are all limited by time. This implies that the organization continuously must adapt to carry out new tasks. Project groups with participants from line groups are created and closed down, when an assignment is completed. Some project members participate throughout the project period, while others carrying out specific task participate in short periods.

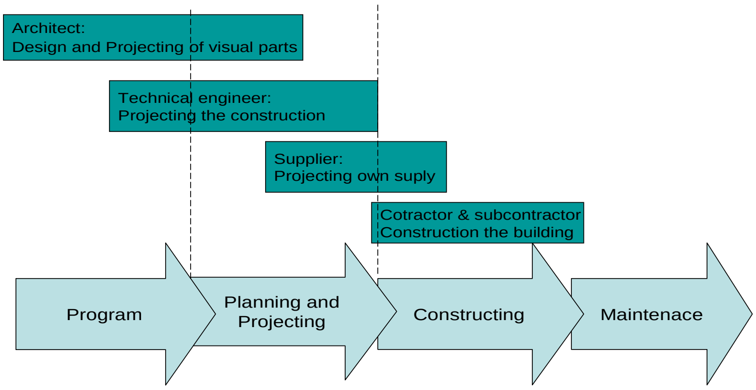
4.1 Project Phases in a Building Project

The first task in a project is to get the contract. Sometimes the company is contacted directly by customers because they know the company from previous assignments or because of their good reputation and recommendations. Ramboll may then make a quote. In other instances Ramboll gets a contract by winning a public tender either alone or as part of a consortium with external partners. Such consortia usually include at least an architect firm and an engineering consultancy company.

When a contract is made the project is designed and a program is set up. Here after projecting is started. In larger projects, both design and projecting will be done in several phases, where still more detailed solutions are prepared and discussed with other partners and the building owner. Following the pre-project phase a tender may be made in order to select one or more contractors to carry out the construction. The building is constructed by one or more contractors. During this phase Ramboll may have responsibilities to supervise or manage part of the project. Finally the project is handed over to the building owner. Sometimes a maintenance contract is also included as part of the project.

The role of the engineering consultancy company varies from project to project. As already mentioned the consultancy may have responsibilities during the construction phase or in the phase of maintenance/operation. Such responsibilities may include employing somebody else to do it, or supervising the work. However there is also a flexible division of work between the architects or the suppliers and the technical engineering company. These differences are very important to agree upon from the outset, as lack of clarity is a current base for conflicts.

FIGURE 1 ***Overview of overlap in competences and need for negotiation of responsibilities***



The number of different partners each with its own responsibilities is in itself a big challenge in all building projects due to the needed interaction. The building process is often described as a stepwise process with a sequential relation between the phases however with some overlap between the companies involved: the output of the architects in the form of an architectural design or a Program (see figure 1) is the basis and frame within which the engineering consultancy companies work out a detailed plan with solutions considering choices of material, sequences, forces, weights etc. (Planning and Projecting). However the visual parts of the building such as facades, walls and alike are often projected by the architects and some suppliers may project their own deliveries. The chosen building contractor and the subcontractors construct the buildings based on the detailed descriptions and plans from the engineering consultancy companies (Constructing).

When a building project is understood as a process of what [17] terms sequential interconnected phases, this indicates that each phase is thought to present well defined tasks and clear responsibilities separated from the other phases as illustrated in the four phase model presented above. It is however not without complications to describe the building process as 1) well defined and 2) stepwise as strong dependencies exists between the different phases and partners. Solutions and choices made by one company frame the possible alternatives for the next company. Developing good solutions (in terms of quality and price) are expected to benefit from a more integrated approach which means that the interconnectedness should be approached as what [17] terms mutual adjustments indicating feedback loops between all the different phases and thus the involved partners.

For instance, the contractor and the engineering consultancy should both contribute to the design phase with their knowledge on solutions, conditions and effectiveness of materials and constructions in order to optimize the entire project. The division of labour between economically independent partners, each with their own contractual obligations and interests complicates the integration of knowledge and agreement on optimal technical solutions across the entire project.

5 Use of Ict in Engineering Consulting

Both industrial players in the building sector and governments have become aware of the need to advance implementation of ICT systems in order to address the above sketched problems. Engineering consultancy firms as well as other players in building projects are now more focused on using ICT as a tool to reduce costs and improve quality in order to respond to growing international competition. This is supported by growing maturity of ICT based design and calculation tools and the possibility of learning from those other industry sectors, which are more advanced in their use of ICT in their production process. In order to facilitate this development, the Danish Government has since the early 90's launched a number of projects. In addition the seven largest actors within building in Denmark have in 2003 created an industry wide organization called BIPS (Building, Information technology, Productivity and Collaboration). The aim of BIPS is to develop collective tools and methods to aid collaboration between all players involved in the construction of buildings. This includes development of common standards for technical solutions for specific design problems. But also common standards for models describing the sharing of responsibilities among partners are developed. In addition, the Government are along with BIPS pushing for the development and integration of ICT based solutions.

The use of ICT within the building sector offers a wide range of new possibilities including more flexibility in production and communication with partners as well as in managing the processes. However realization of potential benefits demands quite some efforts regarding common formats, investments in tools, learning to use those tools, adjusting the qualifications needed and adjusting the business models to the changed processes and products.

Digitalization in Ramboll has been going on for quite some time; however it has mainly addressed mainstream trends such as Microsoft office tools and other standard tools, more lately internal and external networks with implementation of project webs, digital library systems, e-mail and calendar systems as well as more administrative systems. A digital infrastructure is established and much of the communication taking place such as ongoing information and exchange of process information happens digitally removing some of the time and space limits in the company as well as between the partners involved. IT has also been used as production tools for quite a while; especially CAD systems are well implemented in the processes of projecting buildings. The early implementation of CAD systems in Ramboll resulted in an estimated reduction of around 80% of technical assistants. Before CAD engineers made drawings that assistants would then refine, however due to the possibility of manipulating and changing in the drawings, much of this work disappeared very much in line with a lot of secretary work in other sectors. However the change to use of CAD changed the working conditions of engineers quite a bit as it required the engineers to learn to use computers for their work and draw in IT systems. However calculations of weight and forces were still done using pencils and paper. These IT systems mainly affected the work in the companies and not so much exchange of information across partners involved in the building projects.

In this respect 3D modelling is rather different as it is used to cross company boarders. 3D modelling has proved advantageous in a number of different ways, especially in combination with calculation modules and CAD systems makes it a very strong production tool. In addition it can also be combined with a gypsum printer making detailed plaster models. Or it can be combined with virtual reality technology from the gaming world making it possible to make virtual tours looking at the construction from different angles. The combination of these digital models and the different visualization tools has improved the work or service in a number of different ways:

- Visual marketing
- Improving the understanding between partners
- Modelling of complex geometry
- Collision control

- Geometry control
- Reuse of data in models
- Reuse of data across partners

These are some of the advantages already gained from the implementation of 3D modelling this far. In the future compatibility with other systems are a possibility as well as time management, resource management and maintenance management.

3D models are a very convincing marketing tool. Many people have problems in visualizing a spatial constructs from drawings and descriptions. The Gypsum printer which is expensive to purchase makes it however possible to make plaster models in many layers with a lot of details at a cost of 13 euros.

The model can be cut in pieces or made in parts and opened up to look at the construction in side. In the virtual model people can move around inside a building by using a computer. These kinds of models specifically reveals the spatial consequences of the design and can thus be used to get a feeling of the final result and help in discussing different solutions with the customer. This can thus be seen as an additional service to the customer.

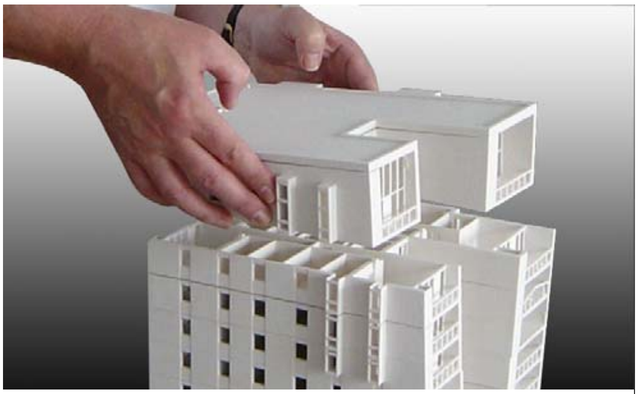


FIGURE 4 ***Layered plaster model***

The same methods can be used in cooperation with partners in the building process. Even these professionals are trained in using drawings and numbers to visualize the construction in their heads. However the concrete models help to reveal where construction and design might be problematic as a common model exist and it becomes easier to discuss and point at the specific point discussed. The use of 3D models has enabled closer cooperation with architects in the design phase. Introduction of 3D models has for instance in the architecture firm Fran O. Gehry disrupted many traditional patterns of interaction among partners as more information was shared. [3]. Other studies show that 3D models can be used to involve contractors already in the design phase.[16]

3D models can be transferred and combined with models from other partners. The 3D model is thus acting as tool supporting knowledge transferring processes providing a common format and a common language and standards (Carlile, 2004). The 3D model thus unites different angles and interests in the model that can be read in different ways serving different professionals with different information. Thus the 3D-model acts as a so-called boundary object [15] – connecting distinct worlds through a common model, whereby it acts as a what Carlile (2004) refers to as translating. Before different models were used for different purposes. Now data from different models can be integrated into one, and in this way inconsistence errors can be avoided. The 3D models also provides for data reuse across the partners, helping to move on much faster, as less repetitive work is needed.

Within the company, 3D modelling allows for more people working on the same digital model. In addition 3D programs make the drawings intelligent, making it possible to reuse data around the model. Changes in reused data just need to be changed in one place to become updated throughout the model. It is also possible to copy part of the model to another part like copying stocks resulting in rationalizing the projecting phase tremendously. However besides rationalization the combination with calculations tools makes it possible to project geometrically more complex models allowing for new types of geometrically complex buildings.

The use of 3D models changes the practice of projecting. It takes much longer time before drawings can be made, as a consistent model needs to be drawn first. Secondly using the tool requires specific qualifications using the modelling system. And thirdly, experience and expertise is needed as this tool has some limitations and the weaknesses in the model need to be spotted. The problem here is that the technology is black boxing part of the process and an understanding of the model and weak points in the technological contribution of the model is essential. The use of 3D modelling also requires some standardization or knowledge of the different measures across the different partners as well as common formats to actually make it possible to exchange, read and understand the models across the different sort of partners. This is complicated due to the shifting partners in the value chain. However the emergence of BIPS has succeeded in supporting these needs by uniting all different partners in an organization working towards these needs.

6 Discussion

Potentially the use of ICT for coordination and production implies dramatic changes in the structure of the technical engineering consulting industry. The most important implications relate to three different types of structural aspects:

1. Internationalisation vs. Local markets
2. Outsourcing vs. Structural integration
3. Division of work between actors within the value chain

Before we embark on the discussion of these three structural questions, it should be noted that the key drivers for introducing new technologies are related to either productivity gains or product upgrades improving the prospects for earning higher market shares. This is in particular true in consulting industries, where costs not related to a specific project are difficult to justify. Therefore innovations – being technical or organisational – are implemented only if they serve a short term need.

The use of calculation models related to 3D models has had a substantial impact on both productivity and quality, as engineers can develop faster and more complicated solutions. The latter is of particular importance for a company like Ramboll specialized in providing unique solutions.

The 3D model in itself does not directly lead to major organisational challenges in order to achieve productivity gains at the project level. However there is a clear understanding of productivity gains in production time. These gains are used to provide for better or more complex solutions or maybe a reduction in price, in both cases this means improved competitiveness in the short run.

In the long run the use of 3D s models will become more widespread. This implies that some of the competences currently available inhouse are codified and built into standard models, which can be developed and maintained by a subcontractor. As these standard models are included in software packages available on the market, this service can easily be duplicated by other companies, and Ramboll will lose its competitive edge. It is therefore important that Ramboll maintains competences, which are difficult to duplicate and which can contribute to better and more sophisticated solutions. According to Ramboll, projecting will become less of a competitive issue in the coming year and that they will therefore be more engaged in consulting. However the experience is that so far the use of these models on complex building constructions is not straight forward, due to the limitations in the systems. There is thus still a need for high projecting skills in ensuring consistent models and complementing the models when they reach their limits.

Reuse of data in other projects creates a similar challenge. Ramboll as well as other engineering companies have developed standard solutions, which can be used in different building projects. By having such solutions embodied in software tools, productivity in the design process can be further enhanced. Solutions become less specific assets, but reuse of such solutions demands transfer of knowledge between different projects. There are visions about integrating knowledge from the different partners especially knowledge from the constructors. Meaning macros on “good” and “workable” solutions should be used instead of newly made solutions. This will reduce costs not only in the design process, but also in the construction phase, where well proven standard solutions considering construction issues are cheaper to implement than unique solutions. This would greatly improve the cost of the entire building projects, however the fear is to what extent such an approach leaves room for creative solutions needed in unique building projecting, and if it would undermine projecting as a unique process and further decrease the demand of high technical engineering competencies.

6.1 Internationalisation

The engineering consultancy industry has been through a series of mergers and acquisitions. These mergers have led to concentration in the national markets and to creation of more internationally oriented players. Internationalisation both opens up for new opportunities in foreign markets and creates more competitive pressure on the domestic market. ICT is an important driver for internationalisation, as it reduces transaction costs related to foreign operations. So far this internationalisation is limited by national regulation and differences in national standards. However there is an ongoing harmonisation on norms within the EU, and this implies that more competition can be foreseen on the Danish market as well as on the other Nordic markets. Still local presence is an important parameter for wining contracts, and local presence is needed to enable good contact with customers and the usually local contractors and suppliers during the project. Also knowledge on local conditions and traditions such as weather and working culture is important, and it might be difficult to serve a lot of different and dissimilar markets in this respect. These issues are among the reasons for having regional offices even in a small country like Denmark.

However, codification and standardization of working processes increase divisibility of the work into smaller modules, where some of them are less dependent on local presence than others. This implies that even though local presence is an important competitive parameter also in the future, most of the work can be carried out on those locations, which offer the most attractive conditions - either in terms of costs or availability of special expertise [2]. This will promote internationalisation of the technical engineering consulting industry, as investments needed to establish foreign affiliates are reduced and economies of scale in specialized functions become easier to realize.

6.2 Outsourcing vs. Structural integration

As noted above codification and standardization of working processes by the use various software tools make some working processes more divisible. This facilitates not only internationalisation of working processes within the company, but also outsourcing of certain processes. There is a clear trend from use of “homemade” project specific software towards purchase of more or less standardized software. This trend enables productivity gains and cost saving, but it also creates new challenges, which will be discussed in the following. The 3D modelling tool is a standard software. Earlier versions were specifically adapted and before that made internally.

Ramboll building section is specialized in providing consultancy services related to construction of unique buildings, demanding use of innovative design and projecting. It is therefore crucial for Ramboll to be in front in using state of the art technologies and in development of new technical solutions. However, in certain areas there is a contradiction between the use of the most advanced software tools, and the development of core technical expertise.

Using a system that black boxes the process and at the same time calls for high qualifications raises a problem of competence building. Due to the increasing use of ICT based modelling tools engineers engage in less assignments and exercises of projecting. Engineers using the tools need to have an intuitive understanding of the complex relations between the various technical parameters in order to use the tools properly, and to evaluate alternative solutions. A part of this understanding can only be gained through practical experience, but when still more parts of the design process are being embodied in various modelling tools, it becomes harder for engineers employed in a consulting company to obtain such an experience.

So far innovation in the technical engineering services in Ramboll has been made as an integral part of the production process. This means that all product innovation takes place in relation to specific projects. The input for innovation is mainly the competences and creativity of the employees combined with wishes and requests from customers or partners. The management of innovation and knowledge is following what [9] calls a personalization strategy. In a personalization strategy the knowledge of the employee is the most important asset as opposed to a codification strategy where knowledge is build into practices or products. With the current development related to the use of 3D we see a move from a personalization strategy towards a codification strategy as a lot of the competencies are built into the modelling and calculation systems.

Software development and development of the technical knowledge, which is built into the software is increasingly divided from the specific project work, and development of technical engineering software becomes a sector of its own. This is a very specialized business with a very limited number of actors at the global market.

The use of 3D modelling tools implies also more divisibility in the design process, as engineers employed in different locations can work on the same model. If situated in different time zones, this can speed up the design process. The potential for outsourcing in this area depends on the kind of assignment. The experiences from Ramboll confirm that complexity of product description adds to coordination costs, as only very standardised tasks has been out-sourced successfully in this way. Work on more complex assignments will often demand detailed local knowledge and intensive contact with customers and other partners.

6.3 Division of Work between Actors within the Value Chain

One of the big challenges is to what extent the organizations should integration their processes across the different partners. The big change with 3D is not technological, but the redistribution of work among partners [16]. This may lead to overall productivity gains, but it might be difficult for the different companies involved to actually realize this and get their share of this productivity gain without constraining themselves too much. Especially there is a fear that the integration will happen at the expense of the uniqueness provided by the different partners.

The trend at the moment is that the use of IT is already leading towards intensified standardization across the building process however at a very basic level. The development of the basic needs for closer collaboration is difficult because it requires collaboration between “unknown” and shifting partners. In the Danish market, Bips has worked for a number of years towards the creation of compatible IT infrastructures and common languages to support for better and closer collaboration. Part of the work has been to develop common formats to make it possible to exchange files. Another area of action is the making of tools to settle the division of responsibility to make the process running more smoothly across the different partners making a better foundation for collaboration by reducing potential conflicts. This work has been quite demanding requiring more iteration to achieve helpful tools without possibilities of unresolved or escaping responsibilities.

In two of the interviews it was stated that another important challenge for the engineers is to understand the working conditions of the contractors. Engineering consultants are often working at a more abstract level, than those responsible for the implementation, and they need to develop an understanding on how the solutions suggested will work out in practice. In some departments, tours to construction sites are made to help engineering consultants to gain this insight however it is still a major an unsolved problem making the knowledge flow across the different phases and partners. Making a system with macros building on the knowledge from different partners will most likely restrain the creativity in the work of the technical engineers and make the move from personalization towards codification much stronger. Using 3D modelling to this extent will further increase the productivity gain however this would require extensive knowledge transformation (Carlile, 2004) of the partners involved whereby the business concepts of each of the partners is renegotiated.

The use of 3D leads to a more flexible structure, with a closer interaction between shifting partners. The coordination costs associated with engagement in new collaborations are reduced through the increasing use of common standards for technical solutions and for digital formats for communication. This creates new business opportunities for specialized companies, which engage only certain kinds of projects where excellence in competences in a particular area is needed.

One of the implications of the use of ICT based models is that engineering consultants today spend much more time communicating with customers and partners and less on preparing technical solutions. Ramboll has their business focus on unique and prestigious building projects. In such projects operating close to the limits of what is technical possible, technical engineering expertise is important. But for other projects, the use of standard models built into commercially available software tools may be sufficient. The entrepreneurs may then be able to do project design themselves and the additional costs related to involvement of technical engineering consultants may be avoided or substituted by costs associated with use of a specialized software tool.

In order to compensate for this, engineering consultants have engaged in new competence areas such involving economics and architectural disciplines. An example of such a new competence area is the design of lightening, which is a new important business area for Ramboll.

7 Conclusion

Engineering consultancies are growing in size and are becoming more internationalized. In addition the building process involves a large number of different actors. These factors lead to a growing need for communication and dissemination of knowledge between different departments and organisations. In this respect the codification enabled by the use of ICT based tools are making these processes a lot easier.

The use of 3D-modelling tools embodies large potentials with regard to productivity gains. These are especially related to reuse of data within project as well as in other projects with similar technical challenges. However, the most visible impact of the use of 3D-modelling tools is not on costs, despite the fact that the production process is becoming cheaper. Instead these cost reductions in combination with the possibilities of more advanced production has enabled design of more complex solutions and higher quality.

The use of modelling tools is black boxing parts of the design process. This implies that much of the expertise needed for carrying out building projects is being codified and embodied in the tools applied. As these tools are becoming more standardised, engineering firms must ensure that they possess additional competencies in order to stay competitive.

Codification of knowledge and the use of modelling tools have enabled exchange of knowledge in standardized formats. At the same time some of the former key competences are built into various types of software tools. This leads to a more flexible structure, where close interaction between shifting partners is made possible. In combination with the ongoing concentration and internationalisation, this creates a market, where companies expand their market reach, and least some companies focus on special competences.

7.1 Limitations and Future Research

In this paper the potentials and related structural consecuenzes of implementing ICT has been discussed. We are well aware that other issues are important when discussing the potentials of ICT such as the implementation and acceptance of the system (see eg. [13; 14])

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