SYSTEMIC INNOVATION IN CONSTRUCTION: THE CASE OF A DANISH STATE DEVELOPMENT PROGRAM

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This paper offers an evaluation of a best practice program called 'Best in Construction' (BiC) which aimed to identify and document cases of successful ICT use in the Danish construction industry. The program is evaluated using two different approaches. The first approach is result-based. This approach evaluates the outcome of the program against the main intentions formulated in the tender material. Drawing on systemic innovation theory an alternative evaluative approach is suggested which focuses on the build-up of organizational and institutional resources to support the development of an emerging ICT trajectory. While the result-based evaluation points to some weaknesses in the quality of the best-practice and cross-organizational elements of the case-material, the systemic approach point to some important side-effects of the program, such as the stabilization and enrolment of the industry-network which carried out the programme. This stabilization and enrolment may turn out to be beneficial in the further effort to promote the ICT use and development of procedures and classifications. It is furthermore found that the problems encountered in the case-study process had a positive impact on the enrolment process of the industry-network.

Keywords: best practice, evaluation, ICT, systemic innovation.

INTRODUCTION

A traditional way of evaluating programs of any sort is to measure the final result against the aims of the program as formulated prior to its realization.

The aim of this paper is to discuss if the learning from such evaluations can benefit from a broader evaluation approach. We find this question especially relevant in relation to the evaluation of broad development programs.

First of all, programs which seek to develop new solutions are often characterized by the contingency of the learning process. Thus, during the process it may be realized that what initially appeared as a relevant framing of the problem is actually inadequate or that the means to meet certain ends turn out to be inappropriate. Such contingent learning processes are not necessarily a problem as they may represent necessary corrections.

Furthermore, broad development processes might be conceived as complex systemic change process, where an alignment of heterogeneous element such as technology, organization, institutional arrangements etc. needs to be established. Programs may be seen as a central means to support such complex alignment processes. These

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characteristic of development processes are likely to be overlooked by the traditional result based evaluative approaches. Thus, additional to the traditional narrow result-based evaluation approach we suggest a broader systemic evaluation approach, which aims to focus on the impact of the program in relation to the further development of the emerging technological trajectory in question. In defining this alternative approach we draw on systemic innovation theory.

The two approaches are discussed in relation to a development program in the Danish construction industry called ‘Best in Construction’ (BiC). This program is one of several elements in a broader development program called “digital construction” which aims to integrate digital communication into the various phases of the construction process and the operation of buildings. The aim of the BiC program was to support the diffusion of ICT tools by providing best-practice cases on existing inter-firm ICT communication in the construction industry.

The paper proceeds as follows. After some methodological consideration the systemic innovation perspective is presented in order to introduce the systemic evaluation approach. In the empirical section the BiC programme is introduced in relation to the other programme elements and programme mechanisms. In order to support the evaluative perspectives the process and outcome of the BiC programme is presented. Finally, this section is followed by a discussion of the two evaluative perspectives and a conclusion.

METHOD

The development of the systemic evaluation approach draws on a systemic approach to technological development originally developed by Carlsson and Stankiewicz (1991) and further refined by Jacobsson (2006). We do not discuss alternative systemic perspectives to technological innovation systems. A number of other concepts could seem feasible such as clusters, (Porter 1990), National Innovation Systems (Lundvall 1992, 2005, Nelson and Winter 1993), local Innovation Systems, (Saxenian 1994), Sectoral Innovation Systems (Malerba 2004), and new forms of cooperation between industry, research and government (“triple helix” Etzkowitz, H and L. Leydesdorff 2000). There are clear overlaps between both the concepts and the phenomena that they represent. We would for example contend that there are several technological innovation systems in play in the Danish construction sector, which on the other hand are in interplay with the national institutional set up.

The traditional result-based evaluation compares the main objective defined in the tender material with the outcome of the program which is 17 case reports on ICT use in the Danish Construction industry. Only the cases on 3D models and Project Webs are discussed as most cases are concerned with ICT concepts within these areas.

The systemic evaluation approach draw on a series of process evaluations carried out by a panel (including the authors) and four interviews with central representatives of the consortium carried out during the program.

Also we interpret the program as strongly embedded in and characterized by the Danish institutional set up. It is a limitation that we do not characterize this embedding and how it impacts on the program. A possible reference for investigating these aspects is Manseau and Seaden (2001). Moreover, studies of innovation in construction and of the Danish construction innovation environment is not dealt with here (see for example Drejer and Winding 2006)

TECHNOLOGICAL INNOVATION SYSTEMS

A main argument by the systemic innovation approach is that the establishment of new technological trajectories is critically dependent on organizational and institutional change as well. Thus, innovation processes may be labelled as systemic to the extents that they depend on a co-evolution of technological, organizational and institutional conditions. Taking such a systemic approach to technological innovation Carlsson and Stankiewicz (1991) defines a technological system as:

"a dynamic network of agents interacting in a specific economic/industrial area under a specific institutional infrastructure and involved in the generation, diffusion, and utilization of technology (Carlsson and Stankiewicz 1991)"

Our view on Technological Innovation Systems (TIS) is influenced by works of Jacobsson (2006).

According to Jacobsson a TIS is made up of (i) firms and other organizations (ii) networks and (iii) institutions. Firms refer to firms within the entire value chain and organizations include universities, research institutions, industry- and other professional organizations etc. Each new firm or organization entering the TIS may bring new knowledge and resources to the system and influence demand or supply.

Networks are formed to develop the necessary complementarities of knowledge and resources. The strength can be characterized by the connectivity of the system. Innovation systems may for example exhibit strong user-supplier connectivity (Carlsson 1997).

According to Jacobsson networks may either be learning networks or political networks. This is, however, a highly analytical distinction, and actual network formation may display a mix both type of processes. McLoughlin *et al.* (2001) underline that learning processes and political processes in networks should not be seen as opposed to each other. The learning processes include the diffusion of knowledge, competences and technology and influence the image or interpretation of desirable and possible direction of technological change. According to Jacobsson the political process of networks refers to the formation of technology specific coalitions aiming to influence the political agenda. This view on political process may be too limited as it has been argued that intra-network dynamics in which the actors are aiming to maximize their control over resources within the network by forming alliances are omni present phenomena (McLoughlin *et al.* 2001)

Institutions refer to the regulatory aspects, influencing the interaction between actors. Institutions may range from informal norms, culture to formal institutions and legal frameworks. Institutions are important to the firms' beliefs regarding what is possible or desirable, to the extent that such beliefs are rooted in routines and norms. Existing institutions may thus counteract changes in the learning structure such as changes to the problem agendas and search principles. Dal Fiore (2007) has conceptualized the conservative learning mechanisms of institutions by discriminating the conserving learning processes of communities of practice, i.e. institutions, from innovation networks. An important function of a TIS is to influence institutional designs, such as the policy on research and innovation, the marked regulation, beliefs and norms.

Thus the systemic approach to innovation offers an alternative evaluative perspective focussing on the extent to which programme elements succeed to shape one or more of the elements of a technological system, i.e. the entry of firms and other organizations, the formations of network and influence on institutional design. Public

R&D- programs would potentially influence on all three elements. Here we focus on the extent to which the best practice programme ‘Best in Construction’ has resulted in systemic innovations in the sense outlined above.

DIGITAL CONSTRUCTION AND THE BIC PROGRAMME

Presently the Danish construction sector is characterized by a number of development programs. The most prominent of these programs is Digital Construction (DC) hosted by the National Agency for Enterprise and Housing, Denmark, (abbreviated EBST), a public body under the ministry of Economy and Business Affairs. The BiC program, which is the main focus of this paper, is one of the elements in this program.

The overall aim of DC is to increase the efficiency of the construction sector by digitalizing the various phases of a construction project. The total budget of the program is approx. 5.5 million £, where the state funding is 1.8 million £, the industry funding is budgeted to 2.7 million. £ and 0.9 million £ has been granted by the foundation Realdania.

As mentioned above, DC is composed of a portfolio of elements. The basic element is the so-called digital foundation, aiming to develop common procedures and classification in order to enable digital communication between entities. Other elements are means to diffuse the implementation of these procedures and classifications to the operation of the industry. A distinct element is the utilization of the purchasing power of the state. Since the 1st. of January 2007, enterprises working for state clients can expect to be met with demand for a digital construction process. Depending on the size of the construction budget, the digital demands are comprised of digital tendering, information sharing by a digital project web, 3D design, modeling and digital commissioning

THE PROCESS OF THE BIC PROGRAM

As an element of DC, BiC was launched by means of a tender process in 2004. The tender was won by a newly established industry network called Digital Convergence (DiCon) aiming to support digital integration in the construction industry. This industry network comprised seven major contractors and consulting engineering companies within the Danish construction industry. In order to meet the demands in the tender material DC formed a new consortium called *Construction – Innovation – technology (CIT),* which also included representatives from The Technical University of Denmark and the governmental research institution The Danish Building Research Institute.

In the tender material the overall aim was defined as the documentation of practical use of ICT concepts by SMEs because the capabilities of the SMEs were identified as critical to the success of the overall programme. The intention was first of all to create business cases in order to provide a basis for decision-making to managers in SMEs. A critical requirement was that the ICT concepts had to include inter-firm communication or information sharing in order to support the overall program aim of ICT integration between companies. It was furthermore the intention to develop a research method to support a long-term collection of business cases.

In the tendering offer by CIT it is argued that:

”The composition of the CIT consortium and the present collaboration between the seven participating contractors and consulting companies in ”Digital Convergence” provides certainty for the identification and/or establishment of 15 cases with the scope and relevance necessary to ensure value and credibility towards the target audience ”

In agreement with the program secretariat the project-consortium decided that projects should primarily be selected from either one of four test projects established under DC (digital tendering, 3d models, project web and digital commencing) or from projects with participation from one of the companies in DiCon.

The identification and enrolment procedures were further specified in a sample selection manual, which divided the case selection procedure into five individual steps, beginning with the identification of potential cases proceeding with the selection of cases and ending with the establishment of case organizations. Some of the key elements in the selection procedure were:

- Relevance to the target audience, i.e. primarily SMEs
- Systemic or holistic: The cases should provide best practice examples into the process from tendering, design, planning, construction, delivery and operation
- Compatibility: the selection methods should be documented, transparent and coherent.

Additional to the sample selection manual a method manual was compiled in order to define a coherent case design. The outcome of this manual was a hypothesis driven case design where each case is evaluated against an initial set of hypothesis identifying possible advantages to the ICT concept. Furthermore the cost of implementation and/or operation of the ICT concept were to be assessed and balanced up against rationalization gains and so-called “qualitative gains”. Finally, factors critical to success and “rules of thumb” were to be identified. The cases were furthermore to be assessed by a quality audit.

During 2005 the programme ran into problems, as the anticipated lead users could not be identified. In the beginning of 2006 the situation became critical and was discussed in a series of meeting between the project consortia and the government agency responsible for the programme. A question which had not been clarified in either the tender material or the offer was if the cases needed to document ICT concept, which supported the legislation-based demands to participants in state projects. As the agency insisted on this, the consortia chose to apply the ICT concepts to an array of in-house projects. By January 2007 the consortia succeeded to deliver 17 case reports.

THE BEST PRACTICE CASES

The 17 best practice cases which was the outcome of the programme can be divided into ICT concepts which are concerned with the areas listed in the Figure below. This list discloses a heavy concentration of cases on 3D-models and application of project webs. These two categories are discussed below. Project webs may be considered a fairy common ICT tool, while 3D models are less mature.

ICT tool	Number of cases
3D models	5
Digital Projekt webs	4
Digital list of defects	2
E-learning	2
Digital Commissioning	2
Digital description tool	1
Email standard	1

CASES ON 3D MODELS

3D models are three dimensional computer models of the building and in DC normally composed of a number of discipline specific models. Two cases (12 and 20) are concerned with the extraction of material quantities from 3D models (creating a bill of quantities). The extraction process was not established as a common business procedure in any of the two cases. Case 12 is very vague in term of case results and mostly discusses potentials and risks to digital tendering and extraction of quantities in general. Case 20 concludes that timesaving was achieved. The cases document collaboration between two and three actors respectively, within the phases of design and tendering.

Case 13 on a refurbishment project evaluates the efficiency of 3D modelling as a coordination tool between different types of installations, also within the design phase. Case 10 is somewhat similar as it investigates if 3D models affect the collaboration between different professions in the design and planning phase. It is concluded that the compilation of discipline-related models into a common model is time saving, that it prevents ambiguity, and that it is efficient in preventing that installations collide. However, only one company is involved in using 3D, since the communication between architect and engineers was done by use if conventional 2d drawing. Case 8 concerns the use of the 3D work method for design in a project, which was stopped before construction. The internal use of a 3D model at a consulting engineer company is assessed. Problems were identified as the ICT tool was not fully developed and the planning of the different professions was not progressing simultaneous. The model for electrical engineering was discarded altogether. It is however concluded that 3D models are an efficient design-tool

The 3D model cases display few examples of established best practices. Most cases points to future potentials for 3D models. Furthermore, the cases are restricted to the design and the tendering phase. 3D models could also be highly relevant to both the construction phase and the operation phase. Last, only ICT use in large companies is targeted and two cases include only a single company while the others included 2 and 3 parties respectively.

CASES ON DIGITAL PROJECT WEBS

The aim of utilizing project webs in construction projects is to ensure efficient and consistent communication and distribution of information and drawings. Two cases are very similar (17 and 14). They test project webs as a tools of communication within and between contractors in the construction phase. A special initiative is the installation of a so-called digital workmen’s hut including a printer to print out drawings. The striking thing about these two cases is that the sub contractors (SMEs) were not willing or able to utilize the project web. Factors critical to success was identified as efficient ICT service and individual introduction and training of the different professions and companies (case 17). In one of the cases the project web was only used by a single contractor while the other included communication between 3 contractors.

In a case on a refurbishment project a project web is utilized between the consultant, the architect, the contractors and the residents. An overall conclusion is that the project web is a success. While the last case also evaluates the project web as a useful tool some preconditions are identified: All parties should be receive proper instruction, a coherent information structure should be established, a proper division of roles.

The cases on project webs are less speculative and more concrete in their evaluations compared to the 3D model cases, as this technology is better integrated in the normal business process. However, also these cases focus on big companies. The subcontractors' very limited ability to exploit the technology discloses fundamental limitations of the utility of the cases as examples of best practise for SMEs. In two cases the use is restricted to the construction phase.

THE TWO EVALUATIVE APPROACHES

In this section the BiC program is discussed using the two evaluative approaches described above. First the program is discussed from the result-oriented perspective and then from the systemic perspective.

THE RESULT ORIENTED APPROACH

As noted in the last section the intention of the programme was to document existing best practices in SMEs in order to establish a basis of decision to managers in SMEs. It was furthermore a requirement for the concepts to be cross-organizational, i.e. to support the communication and coordination between companies.

The value of the cases as examples of *best practice* is limited. First, they are not primarily targeting the SMEs, and thus only marginally relevant to the overall objective of BiC. Secondly, the low number of actors and the barriers and problems identified in processes between them discloses that the route to a digital construction process is still substantial.

The BiC cases are thus largely preliminary to the aim of presenting best practices. This is also reflected in the hypothesis driven case design. The consequence of this design is that rather than presenting best practices, the study presents an evaluation of various cases to see *if* they could be taken as best practices. A fundamental tension in "Best in Construction" is thus that it aims to identify and present best practices, while the working method is actually forced to be preliminary to this aim. By employing a so-called "forward projection evaluation method" (i.e. a speculative foresight method, with elements of a Delphi study) verified by the case participants, in seven cases (f.ex no 5) it is concluded that both rationalization gains and qualitative gains are achievable in the long run. Such very loose couplings between conclusion and premises (the case findings) are considerable jeopardizing the credibility and usefulness of the BiC cases as best practice recommendations. A main cause to this problem is that in most cases the ICT use was experimental. Thus, instead of identifying best practices, the cases are describing experimental learning processes unlikely to be considered as best practices. Another problem from the viewpoint of a best practice perspective is that two of the cases actually provided a partly negative conclusion to the benefits of ICT.

THE SYSTEMIC APPROACH

As discussed above the systemic view on innovation emphasizes the importance of the build-up and enrolment of actors, networks and institution to support the development of the emerging technological trajectories. To the evaluation of development activities the systemic perspective thus suggests that the process of enrolment may actual be as important as the actually production of best practice cases.

Seen from this perspective the most significant outcome of BiC was probably the stabilization of DiCon and the alignment between this industry network and the overall aim of the state development program of DC.

Thus the learning experiences from the BiC were highly unexpected. The aim of the program was to produce example of best practise aiming to show managers of SMEs the benefits of utilizing ICT tools. However, most learning so far actually took place within the consortium, as it was realized that best practice cases could not be found in SMEs. DiCon was further enrolled into the activities of DC as the BiC program ran into problems in identifying lead users. To cope with these problems the companies of DiCon not only became evaluators of the activities of others but rather became directly involved in the testing and development of the ICT concepts. It can thus be argued the problems of providing the anticipated best practice cases has actually lead to a deeper involvement of Digital Convergence into the activities of DC.

The involvement in the BiC program has lead Digital Convergence to focus exclusively on the further refinement and implementation of the procedures and classifications developed in DC programme in 2008. Thus a virtual company has been establishes which has to determine in greater detail how the procedures and classifications can be used to support communication and information sharing between professions and organizations. As a learning and enrolment process the BiC programme has thus proved very efficient.

While the stabilization and enrolment of DiCon into the emerging ICT trajectory defined by DC was highly unintended and largely a side effect of the BiC program, the overall DC program has also been characterized by more intentional network-building aiming to support and stabilize the ICT trajectory in the long run.

A central organizational construct has been BIPS (“Building, Information Technology and Productivity and Cooperation”). BIPS is an association of enterprises and other parties exchanging experiences and developing standards for ICT use. BIPS was given central developmental task within DC and are also foreseen to be a central organizer of the maintaining of the results of DC, such as the new Danish classification of buildings.

Both the intended and unintended network-building processes discloses a layer of companies, institutions and public bodies characterized by a high level of connectivity and dense network formations. The program, however, also shows, that largely disconnected from this layer is the small average SME of the construction sector. Thus a fundamental challenge of DC will be the diffusion of digital tools and processes to these average companies, in order to ensure a general lift of the use of technology. This is essential to the success of broad initiatives such as DC, which is supposed to ensure digital information sharing between all actors and phases of the construction process. This is an immense task, as approx. 70 pct. of the sector is comprised of SMEs (Danmark Statistik 2005).

Thus, from a systemic perspective, an overall criticism of DC is that the alignment process largely reinstate and renew existing hegemonies of the industry.

CONCLUSION

Appling two different perspectives this paper has presented an evaluation of the best practice programme 'Best in Construction'. The overall conclusion is that although the programme has been weak in producing relevant best practice cases to managers in SMEs it has been successful in enrolling and stabilizing the industry consortium which carried out the programme. Thus, the consortium has become engaged in the further development of the ICT trajectory initiated by the programme. Ironically it was found that the enrolment process benefited from the problems faced by the programme as the participants of the consortium had to engage much more in the testing of the ICT-concepts than initially anticipated.

It is furthermore found that the process of the programme reflects some general systemic conditions for innovation in the construction industry. Thus, the industry is composed of a "layer" of big companies and professional organizations, which are characterized by dense network formations and high levels of connectivity. However, the average small company of the constructions industry is largely disconnected from the development in this layer of the industry. Engaging such companies in the emerging ICT development will be a main challenge.

It can thus be concluded that the systemic evaluation approach discloses some fundamental characteristics of the program dynamics, which are not identified by applying a traditional result oriented evaluation approach.

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