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DESIGN–MANAGEMENT INSTRUMENT FOR EVALUATION OF COMMUNICATION AND COOPERATION IN MULTIDISCIPLINARY TEAMS

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1. Introduction

Developing a new product is nowadays a complicated process. Often, organisations have to adjust their approach to the changing market and customer requirements to be able to survive. There has been a shift in focus from production to the earlier stages of design. Firms have therefore reorganized the product development process from a sequential approach to a more *integrated approach* to deal effectively with changes in the competitive environment [Clark and Fujimoto, 1991], i.e. to be successful.

Practice reveals that appropriate and effective communication and cooperation processes in multidisciplinary design teams contribute highly to the success of integrated product development processes. The literature, particularly of concurrent engineering (CE), emphasizes the importance of coordinating activities and practitioners of various disciplines. Communication and cooperation over the boarders of function, culture, location, and time is, however, still raising problems in practice [Wognum et al, 1997] and [Huthwaite, 1994]. Design managers often lack overview on the critical factors that are important in their specific situation for realizing manageable communication and cooperation in their multidisciplinary design teams. The objective of this research was therefore to develop an instrument for design managers that brings insight in the communication and cooperation in multidisciplinary design teams.

To reach our objective, we used the following approach. From a literature study on concurrent engineering (see section 2), we derived three areas for special attention regarding communication and cooperation in multidisciplinary design teams. For each area, we derived a list of critical factors influencing the communication and cooperation (see section 3). This list was the basis for the development of an instrument that shows design managers the degree of teamwork in their design team (see section 4). The instrument was used and tested in three case studies in the building industry (see section 5). Finally, preliminary conclusions about the instrument were derived (see section 6) and recommendations for further work were made (see section 7).

2. Concurrent Engineering

For the development of our instrument, we studied, among others, the following literature about concurrent engineering: [Hartley, 1992], [Huthwaite, 1994], [Paashuis, 1997], [Prasad, 1996], [Wognum and Veenvliet, 1999], and [Wognum et al, 1997]. Information plays a key role in an integrated approach of product development. A design team has to deal with a lot of information about, for example, the client or the market, and the production. This asks a great deal of communication and cooperation in the development process of the different disciplines. In an integrated product development approach, such as described by Wheelwright and Clark (1992), the different disciplines in product development are linked in time and in pattern of communication. The concepts of concurrent engineering emphasise the importance of communication and cooperation in integrated product development. For a definition of communication and cooperation, we follow the definitions given in [Paashuis, 1997]: Communication between functions is seen as a process in which information created in one function is transported and used in another one. Cooperation between functions is defined as the process in which people with different, preferably complementary, knowledge and experience come jointly and by discussion to new product designs. For obtaining more insight in the functioning of teams, we consulted, among others, [Donellon, 1993] and [McGrath, 1984].

3. Areas for special attention and critical factors

Table 1. Areas for special attention and description of the critical factors

Area for special attention	Critical factor	Description
Team approach	Empowerment	To give a team the authority, the freedom, the knowledge and the skills to do what is right to realise the project. The team will better understand the boundaries of the project (money, time, quality) by giving them more "power". The management has still to coordinate, but it has now a collective input from the team members.
	Team organisation	The team should be good organised to function properly as a coherent team. For example, it should be clear which disciplines are when en where needed and what are the goals and procedures of the team.
	Leadership	The manager should not be only managing money, time and quality. The team members need also someone who motivates them, a coach, and guides them through the project.
	Evaluation	The team members should define "lessons learned", based on the knowledge they gained in the project. The management should archive and distribute these lessons.
Coordination	Product decomposition	The product should be seen as a total system that can be decomposed into physical, functional or activity related subsystems, which can be assembled into an integrated system.
	Resource planning	The resources (team members, tasks and time) should be presented in a "Work Breakdown System".
	Interaction process	There should be an overview of the complex relations between the different activities and disciplines in time, to optimise the process of gaining and distributing information.
	Transparent communication	There should be a common understanding of the important project information (e.g. definition list).
IT-platform	Digital designing	Designing with computer software, simulations or artificial intelligence can support the integrated approach.
	Digital administration	By using an integrated project database, the free information flow will increase.

The literature review has resulted in the next areas for special attention: team approach, coordination, and IT-platform (see Table 1). The critical factors in the "*team approach*" area are empowerment, team organisation, leadership, and evaluation. Their objective is to optimise the functioning of the different participants in a (multidisciplinary) design team; members of a design team need to find a balance between the creative part and the formal part of the design process. Product decomposition, resource planning, interaction process, and transparent communication are critical factors in the

"*coordination*" area. They help the design manager to get more grip on his design team by coordinating people, resources, and products [Prasad, 1996]. The "*IT-platform*" area consists of the critical factors digital designing and digital administration, both to facilitate communication and cooperation.
The critical factors in the "team approach" area can be characterised as "soft". This means that these factors influence human behaviour, which is difficult to predict. The critical factors in the "coordination" and "IT-platform" area can be characterised as "hard". These factors bring structure in the complex processes of integrated product development. A certain balance between all these critical factors is needed, to realize manageable communication and cooperation in multidisciplinary design teams in a certain situation.

4. The instrument "MID-web"

The areas for special attention and their critical factors form the main structure of the instrument, called "*Management Integrated Design-web*" (MID-web). The MID-web instrument consists of an *inquiry* to be filled out by the design manager and an *interview* to be hold between a person well known with the use of the instrument and the design manager.

Table 2. Scale division of the instrument MID-web

Level	References	Description
1	Ad hoc, individual and data oriented.	The first level consists of badly defined procedures and chaotic teams. The team members mostly work individually and data oriented. They wait for input and transform it into output with minimum interaction with other team members. The use of IT-tools is inconsistent.
2	Procedures, individual and data oriented.	In the second level there are procedures, but the team members still have problems in communicating and cooperating. This is caused by the individual and data oriented approach of the team members. The use of IT-tools is still inconsistent.
3	Understanding, individual and data oriented.	In the third level the features of the development process are well known by the participants. The team members are still individual and data oriented, but they respect each other's approach and goals. Modern IT-tools are used.
4	Adjusting, team and process oriented.	In the fourth level not only the features of the development process are well know, but also the process is well designed. The individual activities are better coordinated and the team is process oriented. There is an IT-platform.
5	Evaluations, team and process oriented.	In the fifth level the development process is well coordinated and the team members are process oriented. The process, the team performance and the IT-platform are constantly evaluated and improved.

A general scale division, i.e. maturity levels, has been defined for the *inquiry*. The five maturity levels are described in Table 2. The readiness to organize in advance gets stronger with increasing level and the individual and data oriented approach changes into a more team and process oriented approach with increasing level. With the help of the questions of the inquiry, the maturity level of a critical factor can be determined. Each critical factor in the inquiry consists of five questions that correspond with the five maturity levels. The design manager can answer "Yes/No" and the questions have to be answered in the given order. By answering "Yes" he or she fulfils the relevant maturity level of the critical factor and by answering "No" he or she has to go on with the next critical factor. The inquiry is implemented in a prototype in MS Excel. The result of the inquiry is then automatically visualized in the MID-web and gives the design manager an overview of where he or she places emphasis regarding teamwork (see Figure 1).

Our maturity levels are based on the Systems Engineering Capability Maturity Model (SECMM) [Gianuzzi and Garcia, 1995], which is derived from the original Capability Maturity Model for Software [Paulk et al., 1993]. We have chosen for a representation of a continuous maturity model to describe the capability of communication and cooperation processes. The model is a combination of critical factors and maturity levels (process areas and capability levels in terms of [Gianuzzi and Garcia, 1995]). A process area can be mastered at a certain level independent of the mastering of other process areas. This kind of representation is distinct from phase models, in which a key process area of a lower level must be mastered before starting the mastering of higher key process areas. Both types of maturity models are, however, based on fundamental concepts of quality management and organisation science [Gianuzzi and Garcia, 1995].

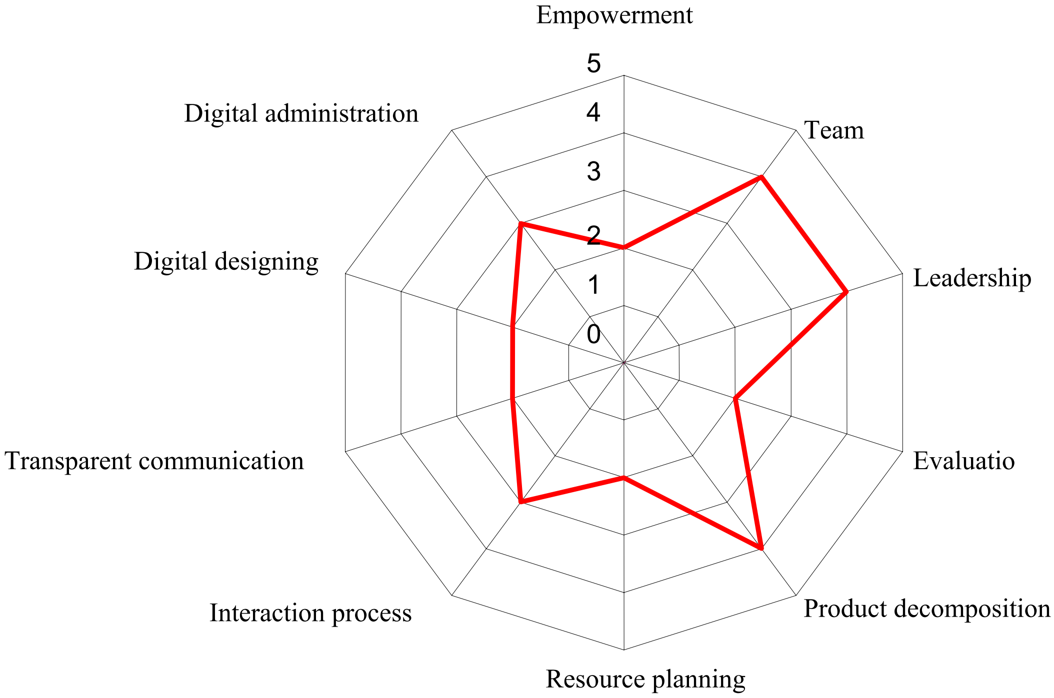

Figure 1. Visualisation of the results of MID-web

In an *interview* that follows the inquiry, first, each critical factor is discussed to check whether the right maturity level is chosen for this factor (a higher or lower level must thus be unsuitable). In the mean time, it is checked whether the questions and levels are correctly interpreted. Secondly, the results of the inquiry, as visualised in the MID-web, are discussed and linked to the success of the design manager in managing communication and coordination. Aspects to improve the communication and cooperation in the team can then be obtained.

Design managers can use the instrument for several projects separately. We made a main distinction between projects with merely internal and merely external parties in the design team. This distinction is made to look for possible different approaches. We assumed that managers would be more open (i.e. having factors on a higher maturity level) when they cooperate with parties of the same company (called internal parties) than with parties they do not often collaborate with (called external parties).

5. Case studies

In the case studies, the instrument was used and the critical factors, the maturity levels, and the user friendliness of the instrument were tested. In the first and second case, the design managers evaluated four different projects (two with merely external parties in the design team and two with merely internal parties in the design team). In the third case, no specific projects were evaluated, but the instrument was used to evaluate the approach of the manager in projects in general. The MID-webs with the results of the projects for each case are given in Figure 2. The webs show differences in maturity level for the different critical factors in each project, between projects, and between cases.

Based on our results, general conclusions regarding differences between projects with internal and external parties cannot be made.

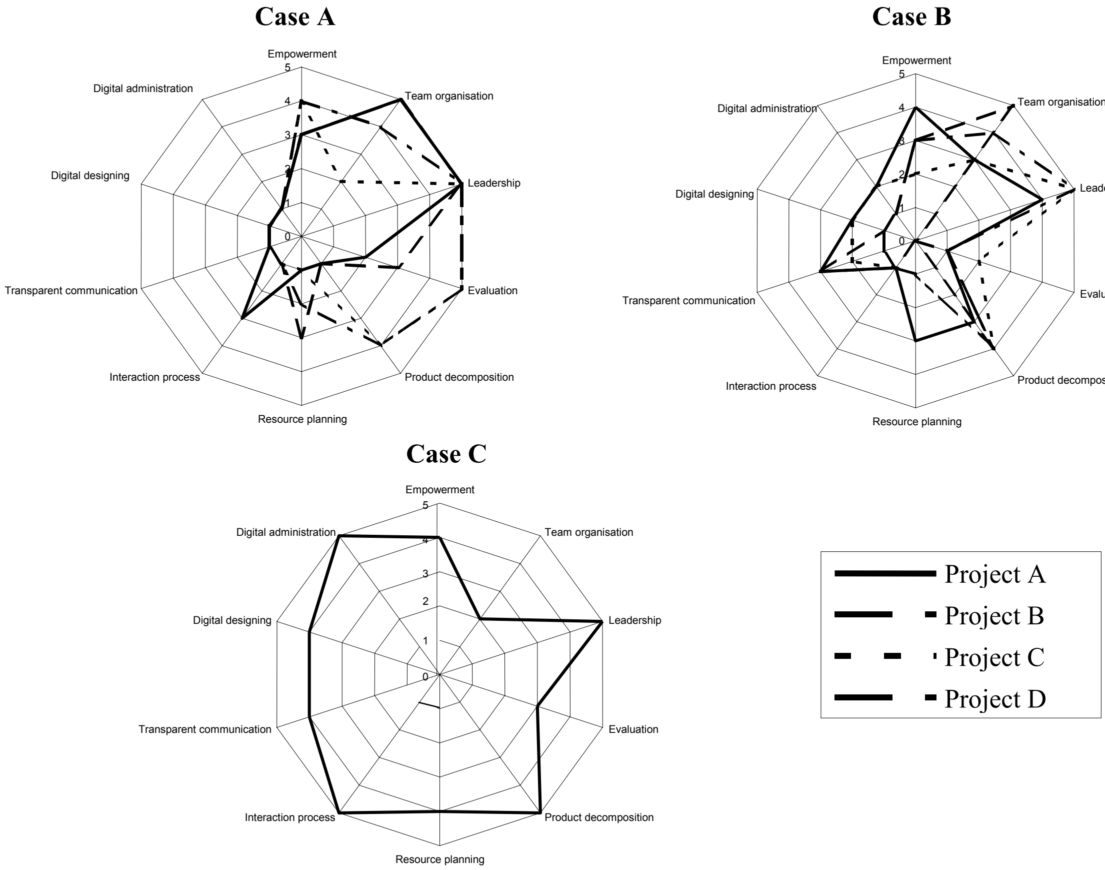

Figure 2. MID-webs of cases studies

6. Conclusion

Conclusions that can be drawn from the case studies are the following. The critical factors and the maturity levels covered the three areas for special attention based on CE sufficiently. The three areas seem to be useful in the building industry to get a better grip on communication and cooperation in multidisciplinary design teams. The inquiry seems to be a good method for determining the maturity level of the critical factors. And, the interview seems to be necessary to link the inquiry results with the success of the design managers. The design managers in the case studies find the MID-web instrument easy to use. Each design manager interpreted the instrument, however, differently, based on his own background. To make the MID-web instrument more usable for design managers (in the building industry), it is necessary to primarily fit the critical factors and the maturity levels with the way of working of the managers, instead of using the instrument as a blue print. More specific,

- the filling in of the critical factors must be made specific for the situation and approach of each design manager (a different set of critical factors can be the result);
- the filling in of the maturity levels must be made specific for the situation and approach of each design manager (a specific question list can be the result);
- an interview must also be planned before the inquiry in order to make the instrument specific.

Conclusions that can be made regarding our scientific contribution are the following. We made an instrument for evaluation of communication and cooperation, focussing on the team level. Similar instruments were made on the corporate and project level (for example, [CERC, 1993]). We made these higher levels appropriate for the team level. Our instrument aims at helping a design manager with getting insight in the communication and cooperation in multidisciplinary design teams. We made a new combination of areas for special attention in multidisciplinary design teams and critical factors for each area, based on CE, with maturity levels for evaluation of communication and cooperation, based on an application of the SECMM. We also implemented our instrument in a for SECMM new way, namely in the form of an inquiry and interview, and a visualised result.

7. Further work

Further research is necessary to refine the instrument and enlarge its possible application area. To define critical factors, other literature than only the CE approach can be studied. It may also be interesting to analyse what happens when team members themselves instead of the design manager fill in the inquiry. Cases should be conducted in other industries than the building industry. When more case studies are conducted, it may also be possible to extract guidelines that may help a design manager in managing the communication and cooperation in multidisciplinary design teams.

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