Organizing specialty competence in product development – the case of robust design methodology

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Abstract
Organizations everywhere are striving to improve quality of their offerings while simultaneously decreasing environmental impact. To continuously improve, there is a need to organize specialty competences within such areas in product development. The aim of this paper is to explore practices for a group representing a specialty competence assisting them in supporting product development. This paper focuses on robust design methodology as a specialty competence. A case study at a large Swedish organization shows that integration of specialty competence requires practices in product development process that seeks knowledge and expertise of these specialists.

Keywords: Specialty competence, product development, robust design methodology

Introduction
Quality Management (QM) is a mature and widely adopted management philosophy. In the past three decades, much has been discussed of QM in terms of its underlying principles, practices and successful application of related tools (Badri & Davis, 1995; Douglas & Judge, 2001; Saraph et al., 1989; Sousa & Voss, 2002). Recent studies are often rather on processes (Kim et al., 2012) and the customization of QM practices to specific organizations (Zhang et al., 2012).

Demands are continuously raised to improve various aspects of products and processes, e.g. continuous improvement (CI) of the quality of the offerings and decreased impact on environment. One way to support this is to organize teams with specialty competence. Specialty competences can be of various kinds, concerning e.g. specific technical competence or methodological competence. One area commonly addressed nowadays being the integration of sustainability expertise. Drawing on this example, Silva et al. (2013) point to three barriers to the implementation of cleaner production (CP) programs into daily operations: lack of integration, lack of continuity, and resistance to change. The first issue concerns that sustainability initiatives are usually implemented "exclusively by environmental departments, which is problematic since this department does not have the authority and expertise necessary to apply CP to the entire company" (Lopes Silva et al., 2012) (p. 2). This statement points to a central challenge faced by managers, namely integration and coordination of specialty competencies in product development (Becker & Zirpoli, 2003). It should be noted that Becker et al. (2003) foremost discuss technical specialty competence, whereas in this paper, the focus is on a specific area of methodological competency within QM, namely Robust Design Methodology (RDM).

RDM is defined as systematic efforts to achieve insensitivity to noise factors, where the efforts are founded on an awareness of variation and can be applied in all stages of product development (Arvidsson & Gremyr, 2008). We argue that RDM is an area of relevance to study as it has been pointed out that this area has historically been focused mainly on tools such as Design of Experiments (DoE), and that there is a need to focus on the practices supporting RDM (Arvidsson & Gremyr, 2008; Hasenkamp et al., 2009). The work on practices has focused on the methodological practices, e.g. to systematically identify key characteristics that are sensitive to variation (Downey et al., 2003) or to work on standardization of parts to decrease probability of being affected by variation in operators' skills (Little & Singh, 1996). However, there is also another side of the practices concerning how to organize the daily work on RDM. In other words, how to organize specialty competence related to RDM; there are few studies on these types of practices for RDM (Gremyr & Hasenkamp, 2011).

The purpose of this paper is to explore practices for a group representing a specialty competence assisting them in supporting product development. This paper focuses on RDM as a specialty competence. The basis for this study is a case at a large Swedish manufacturing company. This paper is outlined as follows; next section discusses the theoretical background, followed by the methodology. The findings and analysis are presented after, and the paper ends with a discussion and conclusion section.

Theoretical Background

RDM has been decomposed into principles, practices and tools (Arvidsson & Gremyr, 2008); where a need to focus on practices has been identified. In specific, a lack of practices to support continuous applicability of RDM throughout a product development process (PDP) has been identified (Hasenkamp et al., 2009). The theoretical background will first address practices of RDM and later move into research on integration of specialty competence.

Practices of Robust Design Methodology

To be able to apply RDM early in PD has been identified as critical (Andersson, 1997; Celik & Burnak, 1998), yet it has been pointed out that most RDM efforts are focused on detailed design phases (Arvidsson & Gremyr, 2008). Morup (1993, p. 181) argues that a "company's ultimate aim with robust design should be to integrate it as a natural part of the standard design procedures, and in the mind-sets of the product developers" (Mørup, 1993). As there is a scarcity of practices and tools supporting continuous applicability of RDM, such integration cannot be based on addition of tools at various stages of a PDP. Rather, in order to exploit opportunities for robustness in all phases of a PDP it is critical to address questions on how to organize RDM work in a way that supports continuous RDM efforts and development of supportive practices (Gremyr & Hasenkamp, 2011).

One way of ensuring practices that support RDM in being continuously applied throughout a PDP is to assign a specific responsibility for RDM to a group or a person. Gremyr and Hasenkamp (2011) studies a company in which one person was assigned as a RDM mentor to support PD project teams in terms of RDM practices and tools. In conclusion they found that (ibid., p. 56) "the principles of RDM do not seem to have permeated the day-to-day work of the company. A key to this missed opportunity could be the lack of explicit practices that can serve as a link between principles and tools […]. The company has likely been aware of the need to bridge the gap between principles and tools and, as a result, has established the role of a RDM mentor. However, it would be feasible if the mentor served as an internal consultant on difficult cases and that all employees working with RDM were equipped with practices".

Hence, a critical aspect is how RDM work can be organized to support a company-wide awareness of RDM.

Specialty Competence: Integration strategy and maturity level
In addressing the challenge of integration of specialty competence, Becker et al. (2003) identified five strategies for knowledge integration in new product development (NPD): organization structures, substitute knowledge by access to knowledge, competence to fill in knowledge gap, decomposition, and physical and virtual artefacts. In Table I these strategies are exemplified by solutions applied within NPD.

Table I. Strategies for integration of technical specialty competency (adapted from Becker et al., 2003)

Strategy	Example from NPD
Organization Structures	Multifunctional teams, concurrent engineering
Substitute Knowledge by Access to Knowledge	Gatekeepers; new managerial roles such as platform or program managers
Competence to Fill in Knowledge Gap	No examples identified to create capacity to fill in knowledge gaps
Decomposition	Integration by standardized interfaces allows for decomposition of complex designs or tasks
Physical and Virtual Artefacts	Use of artefacts to elaborate, develop, test and industrialize concepts that will later be exploited by product managers

The work done by specialty competence can be related to technical competence, but might equally well be a methodological competence such as sustainability or quality. In the latter type of specialty competence, work often aims at improvement of the products or services in terms of e.g. quality or environmental impact. A way to assess how well established and integrated into organizational practice the specialty competence is, can hence be to assess the level of the improvements in the respective area. The work by Bessant and Caffyn (1997) addressed the maturity level of continuous improvement (CI) initiatives. The work was later refined in Bessant and Francis (1999) and Chapman and Hyland (2000). In summary there are five levels of maturity, the first being the lowest level of maturity and the fifth the highest. Table II included labels of the five levels as well as a description of typical characteristics.

Table II. Description of Continuous Improvement Maturity Level adapted from (Bessant & Caffyn, 1997), (Bessant & Francis, 1999) and (Chapman & Hyland, 2000)

Level	Label	Description
1	Trial	Efforts linked to a specific problem solving activity or to an individual with a specialty competence. CI practices are not carried out in a formal structure. The work is localized.
2	Structure	Some associated tools are introduced. Attempts to formalize the CI efforts. Efforts can extend to involve more people but on an ad-hoc basis.
3	Strategy	Structures to link CI to the strategic processes. Formal deployment of goals for CI. Some measurements of the CI efforts established.
4	Autonomy	Top-down structures in place and established, allows for bottom-up initiatives with responsibility devolved to problem-solving unit.
5	Learning	CI is the way businesses are done and has become natural.

Methodology
The paper is based on a case study of an organization operating in a project-based structure, where a group of specialists in RDM tools is set-up under the name Design for Robustness (DfR). Eisenhardt (1989, p. 534) defined a case study approach as “a research strategy which focuses on understanding the dynamics present within a single setting” (Eisenhardt, 1989),

hence being an approach suitable to capture interactions between a phenomenon and its context (Dubois & Gadde, 2002).

The context of this study is a large manufacturing organization with its own product development and production at a single site in Sweden. The organization employs about 2 000 people, and produces high-tech products on a global market. Throughout this paper the organization will be referred to as Alpha, due to confidentiality reasons.

Data Collection

The study is based on interviews with 13 personnel of the product development projects, chosen for their roles in various active projects at different stages of completion. These roles comprise of so-called leaders with responsibilities of the overall project, manufacturing, design, quality, procurement and cost. Further, two of the DfR specialists were interviewed. All interviews but one were conducted face-to-face; one being a telephone interview. Each interview lasted between 30 to 60 minutes. All interviews were recorded and transcribed.

The interviews were semi-structured to allow for the interviewees to decide what and how much they would like to discuss for the topics included (Westlander, 2000). An interview guide was developed to ensure coverage of the research area (Dawson, 2002). Examples of questions were: Do you have any experience of being involved in RDM activities? If so, can you describe these experiences? What practices or tools did you apply? Have you been involved in working with the DfR group? If so, in what ways? Was it useful? How could it be improved?

In addition to the semi-structured interview an evaluation of the use of 19 tools from the QM and RDM area was filled out by the interviewees; assessing: level of use (1 (not at all)-5(regular)), perceived usefulness (1 (not at all) to 5 (very useful), and knowledge level (1(none) to 5(can apply independently)).

Data Analysis

The data was then analyzed by using the NVivo10 program; designed to support analysis of rich qualitative data (Richards, 1999). Before starting the NVivo analysis both authors, individually, read the interview transcripts looking for themes in relation to QM, RDM, and various practices related to RDM – both as a methodology and as a specialty competence. The themes were color coded and provided the bases for the NVivo coding (Hutchison et al., 2010; Walsh, 2003). The main coding categories in NVivo were Quality Management (QM), Robust Design Methodology (RDM), Design for Robustness (DfR), and sustainability. Under each category various subthemes were addressed, related to tools used, perceived needs for changing practices, and challenges in the present ways of working.

The analysis was based on a number of functions available in NVivo, such as text search queries, word frequency queries, and cluster analysis (Bazeley, 2007). The analysis was presented to two members of the DfR group to obtain their feedback to enhance the confidence in the findings (Eisenhardt, 1989), and pointed to areas they perceived interesting for further analysis.

Findings

One general question that was included in the interviews of all the PD personnel was: “What are the main challenges of your role in PD?” Figure 1 shows a partial result of a text search in NVivo on the word ‘challenges’ in the transcribed texts of all those interviewed. The figure below shows sentences before and after the word ‘challenges’ and due to space constraint, it is restricted to display 10 words on each side. A maximum of 99 words are allowed in a text search. A text search containing 30 words on each side was done to derive the challenges into four main elements; time, resources, products and requirements.

Figure 1: Sample of text search from NVivo

Time constraint was identified as the main challenge by almost all interviewees in their roles in PD. This includes short lead times from external and internal customers, long response or wait time between information or document hand-overs, and unexpected delays due to quality problems or manufacturing downtime. The manpower resources from each department are divided between the PD projects. This is not done in a structured manner. The request for resources comes from the project leader, who is selected based on his or her product expertise. The products are divided into three structures depending on the underlying techniques. Each structure has one or two project leaders. The selection of other members of the project team is mostly dependent on their expertise of the specific product. Nevertheless, it is somewhat based on the preference of the project leader according to his or her experience from past projects. All interviewees have been in employment at Alpha between 5 to 30 years. Therefore, past experience of working in project teams plays an important role in team selection. A good team spirit was sensed in a project where all members are familiar with each other based on good past experiences.

The products and its specific requirements that come from customers are strictly adhered to in the projects. Some projects exhibit customer involvement throughout the project on specifications, modifications and knowledge sharing. The products are developed under strict adherences to high safety requirements from customers. Additionally, the life cycle of products varies from mere minutes, and up to a lengthy 30 years. High safety features and varying life cycle requirements result in high project related costs. These three demanding features (safety, life cycle and cost) of projects create a high sense of involvement and commitment from team members.

Project requirements, similar to product requirements, are also mostly asserted by customers. The projects are considered highly customer focused, and the requirements, customer driven. One fundamental requirement of all projects is risk analysis. The product risk analysis is carried out with Failure Mode, Effects & Criticality Analysis (FMECA). The level of use and perceived usefulness of FMECA was rated high by, for example, project leaders, design leaders and manufacturing leaders. However, supporting the application of FMECA in projects is the responsibility of the DfR personnel. In fact, the DfR group is recognized in projects for their task of applying FMECA. This is somewhat exhibited in the word frequency query of the interview texts in NVivo. The term used for this query was 'design for robustness' and the result is shown in Figure 2. The query results in a compilation of all words associated with 'design for robustness', where the font size of each word is an indication of the frequency it appears in relation to the term. The figure shows 'risk' in the largest font size, followed by 'projects', and so on.

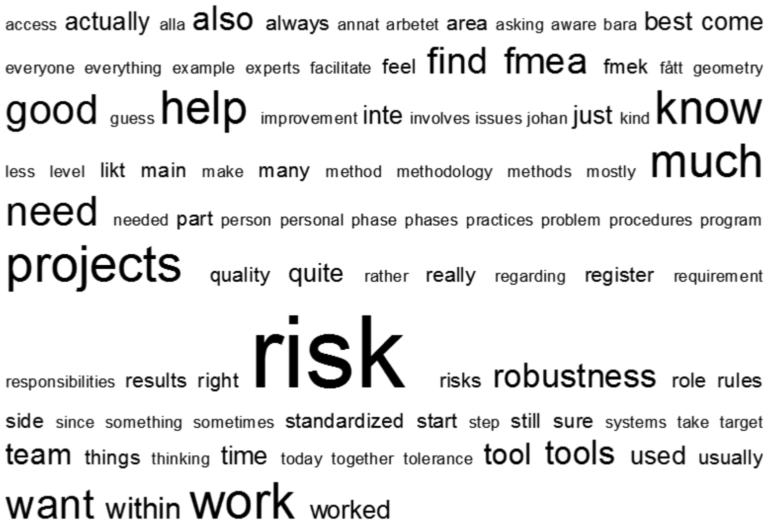

Figure 2: Word frequency for design for robustness from NVivo

In addition, the interviewees were asked of their understanding and knowledge of ‘robust design methodology’, ‘quality management’ and ‘sustainability’. Text search and word frequency queries were done accordingly for these terms. In the case of ‘robust design methodology’, the PD personnel were found to perceive it as ‘producibility’ and ‘easy manufacturing’, in general. RDM was regarded as a methodology used for easy manufacturing of products, where focus of application is in the manufacturing stage. For the same question, when asked to the two DfR personnel, the responses were as captured below.

“Our main issue is to control variation and to control variation we need certain thinking: How to get understanding and knowledge of variation. Therefore we are very much data driven to use all design knowledge and statistics. Robust design is making products insensitive to variation.”

“Robust design means you have to take care of all kinds of variation and how we want to do that in the best way. Also it is a way of taking care of and identifying noise factors.”

The PD personnel are found inclined to an understanding of RDM in terms of manufacturing processes, whereas the DfR group explained RDM in terms of variation and noise factors to be considered during design stage of products. This could be seen in the cluster analysis shown in Figure 3, where the interviewees are clustered in 5 clusters, each color representing a cluster coded similarly based on their responses to all questions. The clusters show that 2 DfR members are clustered away from the rest of the PD personnel. DfR1 and 2 are clustered in dark and light blue colors, respectively, whereas 9 PD personnel are clustered in brown in the middle of the figure. Two other clusters are made of 1 PD person in green and 3 PD persons in purple. The differing clusters of DfR1 and 2 could be attributed to their positions, an engineer and a method specialist, which results in differing tasks and responsibilities within the PD projects. Numbers 1 and 2 indicate the number of people interviewed within the roles. For example, Project1 and Project2 indicate project leader 1 and project leader 2.

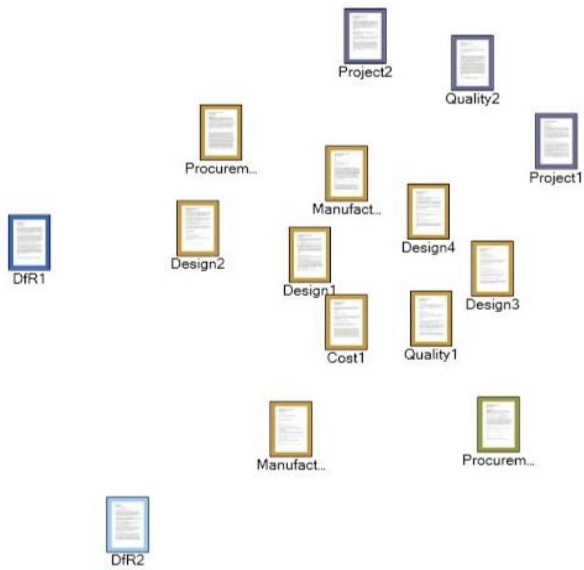

Figure 3: Five clusters of coded responses from NVivo

Similar analysis showed somewhat uniform understanding across the board for ‘quality management’. However, ‘sustainability’ showed lack of understanding, overall. When explained further the meaning in terms of economic, environment and social sustainability, the words ‘environment’ and ‘requirements’ seem to emerge from the word frequency query. The knowledge of sustainability in the PD process was lacking. No conscious considerations were made to address sustainability in PD efforts. However, when the question was directed towards economic sustainability, product and project cost discussion emerged. Product weight limitations are one customer requirement closely monitored in the case of one product where the functional efficiency is dependent on the weight. The efficiency is then measured in terms of cost, where high efficiency translates to less application cost. This customer requirement is not channeled through sustainability measures into the PD efforts, but as a general requirement.

Analysis

Looking at the findings from this study there is a group of people with a specialty competence that organizationally are separate from the development projects, but are assigned to support them in terms of RDM knowledge. The work by Becker et al. (2003) on strategies for knowledge integration in NPD (organization structures, substitute knowledge by access to knowledge, competence to fill in knowledge gap, decomposition, and physical and virtual artefacts) address integration of competence. In the case studied the specialty competence is a methodological one, nevertheless analogies to Becker’s five strategies are found.

At the outset, just establishing a DfR group is in itself an integration strategy, i.e. the strategy of ‘organization structures’ in Table I. The creation of this group is further a way of providing access to RDM knowledge, linked to Becker et al.’s strategy on substitute knowledge by access to knowledge. However, unlike gatekeepers interacting with project at gate reviews in a PDP, the DfR team has no formal access points into the PDP. It is therefore not evident neither for the PD teams nor the DfR group when RDM activities should be initiated. Coming to the strategy of competence to fill in knowledge gap, this is a challenge for the organization studied. As it appears there are no gates in the projects to force reflections on variation and robustness, there are few chances that team members will consider/realize a need for the competence that the DfR group has. A notable aspect, however, is that a member of the DfR group has become known for being knowledgeable in FMECA. As this tool is compulsory for the PD teams this is an area of competence that the DfR group is recognized for, and where their competence is asked for. The fourth and fifth integration strategies, decomposition and physical and virtual artefacts are more linked to integration of technical specialist competence than the type of methodological competence studied in this paper.

In summarizing the integration strategies, it appears as if there is a need for a more elaborate role of the DfR group. If the group is to function in a role of integrator of RDM knowledge, a way forward might be to strengthen the role of gatekeepers by inserting access points, or triggers, in the PDP where PD teams need to reflect upon robustness. Hence, a pull should be created within the teams for RDM competence, just as in the case of the FMECA.

Looking at how well established RDM efforts are in the organization, it is argued to be one possible way to evaluate the use, and integration, of the DfR group's competence into PD. On an overall level, Figure 3, point to a situation where the views on RDM varies between the PD team members and the DfR group members. A DfR group member emphasizes that "our main issue is to control variation. […] Robust design is making products insensitive to variation." The PD team members, however, view RDM as more limited to having to do with 'producibility' and 'easy manufacturing'. One might then wonder at what levels of maturity RDM activities in the organization are? Related to the work on maturity levels of CI initiatives by Bessant and Caffyn (1997), Table III contains an analysis of the RDM efforts at the organization studied.

Table III: Description of RDM activities related to Continuous Improvement Maturity Level

Level	**Label**	**Conceptual Description**	**Case Findings**
1	Trial	Efforts linked to a specific problem solving activity or to an individual with a specialty competence. CI practices are not carried out in a formal structure. The work is localized.	The RDM competence is associated with two individuals, one seen as a risk specialist and one geometry assurance specialist. RDM approach depending on individual.
2	Structure	Some associated tools are introduced. Attempts to formalize the CI efforts. Efforts can extend to involve more people but on an ad-hoc basis.	DfR group is an initiative to formalize RDM efforts.
3	Strategy	Structures to link CI to the strategic processes. Formal deployment of goals for CI. Some measurements of the CI efforts established.	Formal structures to link RDM efforts to the PDP and measurements of RDM efforts appear lacking. Exception of FMECA.
4	Autonomy	Top-down structures in place and established, allows for bottom-up initiatives with responsibility devolved to problem-solving unit.	-
5	Learning	CI is the way businesses are done and has become natural.	-

As seen in Table III, RDM efforts within the organization are mainly localized and dependent on specific individuals. A sign of this is the fact that, views on RDM differs considerably between DfR group members and PD team members (see Table II). It appears to be a situation of outsiders and insiders segregation. To lift RDM efforts to a higher level of maturity, other integration strategies (in line with Becker et al. (2003)) appear needed. This could concern elaborated and formalized links to the PDP, creating a situation where RDM competence is actively asked for and concerns of robustness are continuously considered. Comparing to sustainability, an area where there appears to be less formal attempts for structured support in PD than with RDM, the sustainability requirements linked to e.g. decreased weight are continuously cared for as these are part of the formal requirements that PD teams work with.

Discussion and conclusion

The purpose of this paper is to explore practices for a group representing a specialty competence assisting them in supporting product development. In an organization where RDM expertise is assigned to support PD efforts, the challenge remains in organizing this specialty competence for efficient implementation through proper integration. This need has been pointed out in various areas such as cleaner production (Lopes Silva et al., 2012) (p. 2) and in technical expertise in PD (Becker & Zirpoli, 2003).

In this study, it appears as the DfR group is viewed as an outsider within the circle of PD. This is due to various reasons. Insufficient support in terms of number of DfR specialists per PD project teams is one reason. In this case scenario, four PD projects running simultaneously at various stages of completion has 2 DfR specialists at their disposal in assisting with RDM work, and in addition the specialists support more projects in various ways. One DfR specialist is supporting project risk analysis by use of FMECA in all projects, while another specialist is part-time assigned to one project as a full member in the PD team. A convenient solution in work division is seen by project leaders when project risk analysis is assigned to the DfR specialist, as this frees the PD members of the task. Further, this solution also frees them of the burden of gaining knowledge and insights of RDM work and tools. Another reason is requirement of product and project specific knowledge of the DfR specialists to enable them to provide expertise and support in different projects. The DfR group is organized as a separate organizational unit outside of the PD projects without specialized knowledge of the products in terms of design, engineering or manufacturing. This and the fact that the DfR group does not function as a gatekeeper (Becker et al. 2003) with a natural access point to the PDP, the natural integration of RDM work into PD does not happen. On the other hand, according to the project leader who had the opportunity to work with the full time DfR specialist, the benefits of RDM work is acknowledged and the competence is welcomed for future projects. The latter is an example in which integration has occurred and hence the maturity level (Bessant and Caffyn (1997)) of RDM efforts in that group is higher than in the other projects, seen as linked to the strategic work within that team.

In summary, this study supports Morup (1993) in pointing to the need of integrating RDM into standard product development work. From this study, it appears critical to support PD with RDM specialist competence by establishing practices in the PDP through which RDM knowledge is asked for. Hence, the stated "lack of explicit practices that can serve as a link between principles and tools" (Gremyr and Hasenkamp, 2011, p 56) is here proposed to be addressed by a combination of a team with specialty competence and explicit links to RDM in the PDP. Further, as exemplified with the FMECA, key methods related to RDM that are of strategic importance could be required in the PDP; creating a pull for RDM competence. The latter should, however, be applied restrictively not to create an overload of methods.

The area of specialty competence is not limited to technical competence, as shown in this paper addressing a methodological competence. Rather, future studies could expand on how various types of methodological competences such as in sustainability and QM in general could be organized, or potentially even co-organized.

Acknowledgements

This work has been carried out within the Sustainable Production Initiative and the Production Area of Advance at Chalmers. The support is gratefully acknowledged.

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