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ENGINEERING MANAGEMENT FOR INTEGRATION

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Abstract

A pilot research study addresses the need for new views on the management and organising of engineering. Contemporary engineering organisations are becoming increasingly diversified and disperse. The struggle to accomplish integration of the product development process as well as the whole organisational is harsh and existing theories provides few directions for how to accomplish this. Drawing on the concept of Engineering Management, the paper identifies significant fields for future research, e.g. competence integration, process models for project integration, multi-project integration, and integration of short and long-term perspectives

Keywords: Engineering management, integration, product development, process models, multi-project management, sustainability

1. Introduction

Contextual changes motivate a fresh look at the management of engineering work. Companies of today struggle with how to meet emerging new challenges, such as increased demands for customer orientation, stronger links between business development and R&D, more complex products demanding competence integration, functional sales, outsourcing, globally distributed development teams, new co-operation forms between partners, increased demands on environmentally sound products, and as a result increased risk for overload, stress and burnout of engineers and project leaders. Maybe most profoundly, there seems to be an emerging contradiction in engineering between the short–term productivity and long-term development for future competitiveness.

Modern management has evolved from the rise of mass production and Scientific Management of the early 20th century. The current version of this paradigm is Lean Production. With Japanese production management as the model, there has been a strong emphasis during the last decades on customer orientation, lead-time reduction, just-in-time production, supply-chain management, and zero-defects. Currently, the same thinking is applied on product development; with the aim of reducing lead time between project initiation and finished product launch, the concepts of parallel activities, heavy weight project managers, cross functional teams, and simultaneous engineering have been introduced. Similar ideas are also preached by popular theories such as Process Management and Total Quality Management. All these approaches emphasize operational efficiency through process-orientation, streamlining, and standardization of tasks. In other words, product development and engineering work are supposed to be managed according to the same principles that have guided manufacturing management during the past 100 years.

At the same time, however, studies of the empirical practice have shown that time-focused development projects tend to utilize less tight control structures. In such projects, goals are often renegotiated during execution, changes in staffing and scope are frequent, project team members are not given distinct positions in the organization but expected to find – and define - their own role during project execution, and external partners co-operates in the projects to a significant extent. Taken together, these anomalies indicate that the old success approaches of the past (however, taught in a modern language) might be obsolete Instead, new methods, models and strategies are needed.

This paper inquires into the challenges facing the management of engineering in product development. Anchored in interviews in six major engineering companies in Sweden, it addresses the following two questions:

1. Which are the most significant issues for contemporary engineering and product development?
2. Given these issues, which are the key areas for research in order to create long-term effectiveness and sustainable working conditions?

2. Frame of reference

The paper is a part of a research initiative on Engineering Management. This label has been used by several different meanings, encompassing a number of non-technical issues in the context of product development and engineering work [c.f. 1, 2, www.ieee-iemc.org]. In this paper however, the concept engineering management denotes "the practical management of technical development processes". Thus it is the managerial practices forming the empirical conditions for product development that constitute the point of departure of the paper.

Considering today's harsh pressure on short-term productivity in product development, the ambition of this initiative - which this paper is a product of - is to develop models for the management of technical development and innovation processes in order to combine the pressure for short-term efficiency with the need for innovativeness and sustainable work systems for long-term effectiveness. One basic assumption, thus, is that it is possible to find approaches that contribute to all three factors. However speculatively, we assume that these factors actually presuppose each other [3].

Theoretically, research relevant for this field is carried out within a number of theoretical discourses, of which several are overlapping. Without excluding other schools of thought, four discourses are identified as especially relevant (see fig 1): Engineering Design Project Management, Innovation Management and New Product Development, and Organisational Research on Product Development. However, an exact distinction is not possible nor meaningful, as one key point in our view is that empirical issues define the field, not one or a few specific theories.

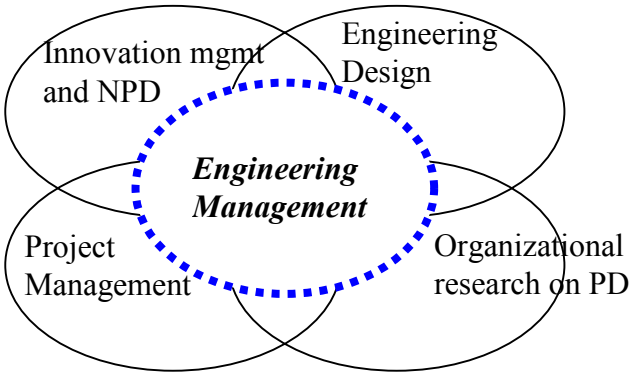

Figure 1: Theoretical foundations of Engineering Management

The first discourse is Engineering Design. Departing from issues of a technical nature, several contributions within this line of thought also address the technical processes, tools, and methods in engineering practices [4, 5]. This discourse tends to have a normative and rationalistic basis. Typical issues related to our interests are design processes, product development work procedures, support methods, collaborative work, development and implementation of IT tools, and creativity in design [6, 7, 8]. The units of analysis have often been the single method, the single product, or the single development project, though increased efforts are put to expand the unit of analysis [9, 10].

A second discourse is Project Management, which originally was dominated by practice-oriented project management literature and research on methods for planning and scheduling. During the last years a small, but growing, research stream have evolved with more descriptive approaches to research on project organising and project work [c.f. 11, 12, 13, 14]. However, with some exceptions, the dominating focus is still on the management, control, and organising of singular projects, primarily from the point of view of the single project manager.

A third discourse is Research on management of innovation and new product development (NPD) has primarily revolved around issues concerning the innovation process in a broad sense and contextual factors enabling an innovation climate [15]. Concerning engineering management, contributions address the nature of the development process, lead-time reduction, customer involvement, structuring of the development process, how to manage "the fuzzy front end", and product portfolio planning [16, 17, 18, 19]. Traditionally, the perspective has been the single project. Contributions addressing issues on an organisational level, has primarily influenced by the studies in close relation to the concept of Lean Production [20, 21].

A fourth discourse is organisational theorists studying product development [22]. The discourse relates, among other things, to the classic discussion on organisational design and matrix structures [23, 24]. The traditional unit of analysis is the organisation as a whole, not the individual project. In relation to engineering management two contributions are of specially interest: First, [25] which shows that lead-time reduction is not that easy as just compressing traditional activities on a shorter time-schedule. Secondly, [22] that questions the classical dichotomy between organic and mechanistic organisational structures.

To conclude, the core of Engineering Management is a set of empirical issues, which are derived from the practice of managing product development. The theoretical basis, which addresses these issues, is multifaceted, fragmented and contribute to insights on different levels of analysis. Accordingly, there is a need for research that integrates earlier findings, theories and models as well as issues that cuts across different levels of analysis.

3. The pilot study

An empirical exploratory study was carried out during the winter 2001-2002. The over-all purpose was to investigate the state and conditions of practical engineering management in leading, technology based companies in Sweden. Furthermore, our ambition was to identify issues for future research, which are of critical importance for the contemporary management of engineering.

3.1 Sample

Six R&D-organizations of different companies were included in the study. The organizations belonged traditional and mature industrial companies with a strong position in their respective

market and a successful history of innovation and product development (for an overview, see figure 2). The companies were chosen for two reasons. First they were considered as good representatives for contemporary engineering industry of Sweden; critical issues in these companies will probably be critical in other companies as well. Second, they did all show an active interest in developing their engineering management capabilities.

	ABB Research	Assa-Abloy	Bombardier	DeLaval	Electrolux Floor care	Pharmacia Diagnostics
Core Products	Corporate research projects	Locks Security systems	Trains	Milking Systems	Vacuum cleaners	Medical equipment
Industry	Electrical	Mechanical	Electrical	Mechanical	Mechanical	Medical
Market	Corporate Management	Consumers	Professional Customers	Professional Customers	Consumers	Professional Customers

Figure 2: Overview of the studied organizations

All the studied organizations belonged to a large, internationally active, parent corporation. However, they represented three industrial sectors; three of the organizations were based within classical mechanical industry (Assa-Abloy, DeLaval, Electrolux Floor Care), two came from electrical industry (ABB Research, Bombardier), and one represented the medical-technical industry (Pharmacia Diagnostics). As will be subsequently discussed however, the boarder of these industries seems successively to become more vague and diffuse.

One of the studied organizations was a corporate R&D unit (ABB Research), three developed products for professional clients (Bombardier, DeLaval, Pharmacia Diagnostics), while two developed products, primarily for consumer markets (Assa-Abloy and Electrolux Floor Care). Furthermore, the products of the companies differed in terms of complexity. While e.g. ABB and Bombardier are systems suppliers providing their clients with tailored complex product systems, Assa-Abloy, Electrolux and Pharmacia Diagnostics are developing products to be produced in high volumes on the mass market.

3.2 Method

Since the objective was to raise issues for development of new theories, not to test existing theories, an inductive research approach was chosen. Data has primarily been acquired through second semi-structured interviews with leading representatives of the organizations. Approximately two respondents were interviewed at each organization. The interviews lasted between one and two hours and had the character of informal dialogs. Most questions where open-ended, such as “Which are the greatest threats …?” or “Can you explain …?” in order to make the respondents to elaborate on present challenges and conditions. Hence, emphasis was put on the respondents’ definitions of crucial issues for practical management.

Two researchers conducted each of the interviews. Both interviewers took written notes. These notes were transcribed, compared, and merged into one case description for each company. Thereafter, the six case descriptions were analysed by the whole research group together, in order to identify any the empirical patterns.

4. Findings

This section structures the findings from the interviews into three levels; the strategic level of the company, the organizational level of the R&D division, and the level of the single development project (see figure 3). In practice, these levels are closely intertwined with each other.

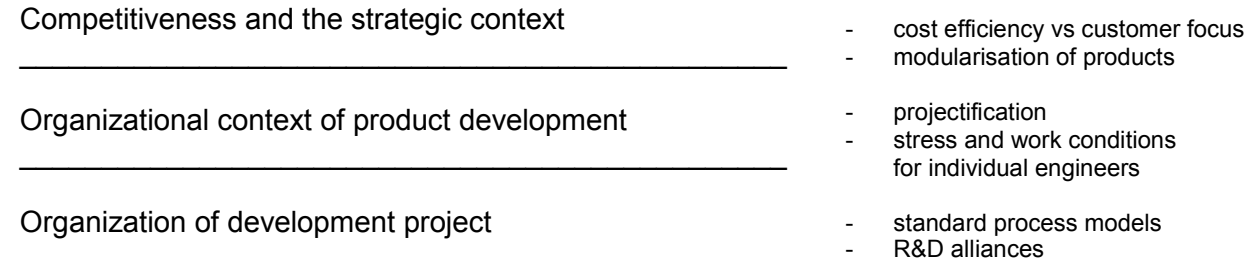

Figure 2: Issues at three levels of analysis

4.1 Competitiveness and the strategic context

On the overall level, two types of competitive strategies could be distinguished: *cost-efficiency* and *customer-focus*. The former included long product series, a focus on price as competitive weapon and the use of retailers for distribution. The latter was common among companies with a direct relation to the customers. The ability to adapt and solve specific customer problems was decisive. Consequently, there was a strong demand on tools and methods projecting the future developments of markets and customers.

The majority of the companies emphasized *modularization* as a strategic approach for offering complete product systems, as well as for increasing efficiency in R&D. Modularization had been on the agenda, but it is still considered important since it was believed to support both the cost-efficient as well as the customer-focused strategy.

Another strategic issue was *functional sales* i.e. to offer the product as a service carried by a physical product. The driving force for this strategy were claimed to come from the customers, not from the within the producing companies. Functional sales was claimed to affect the practice of product development since it increases the need for understanding the businesses and practices of the customers.

4.2 Organisational context of product development

The dominating form for organising product development was the matrix organizational structure. The operational engineering work was typically organised in *projects,* drawing on technical expertise from different functional departments. There was a broad consensus of the advantages of this approach among the respondents.

However, an increasing emphasis on lead-time in product development and the short-term project goals put high pressure on the individual project members. In general, to be engaged in demanding projects were seen as motivating, but all respondents announced strong concerns about the consequences on individuals' health and *risk for staff burnout*. In general, several respondents wondered how "lean" development organizations could be in the long run.

The companies experienced that they had good ability to manage information technology (IT) as a tool for product development. From a technical point of view the systems worked well. However, there were financial worries about the increasingly larger overhead cost for IT.

4.3 Organisation of product development projects

All the studied organizations had a *standardized formal model* of the product development process, which was considered as successfully implemented and well used. In a couple of companies formal processes existed on local level, but not on the corporate level. The advantages of process models were claimed to be shorter lead times and better fulfilment of specification due to the possibility to plan and control the process. This was in particular the case in companies, where the application of process models had become internalised as an engineering habit.

In general, process models were seen as good for incremental development projects. They were more difficult to apply on radical innovation. Furthermore, methods for identifying bottlenecks as well as an ability to adapt the process model according to project size was asked for, however.

All the respondents regarded their companies as good at *cross-functional integrating* in particular between product development and production. However, the studied organizations are still suffering from harsh integration problems, e.g. in the technical interface between mechanical and electronic engineering or in the administrative interfaces between engineering and the purchasing department or marketing department.

A critical issue raised in all interviews was how to collaborate with external partners in *R&D-alliances*. Due to strategic outsourcing and increasing development costs, there was a strong pressure to run development projects drawing on resources from e.g. competitors, sister-companies or suppliers. However, there was a lack of knowledge about how such alliances should be coordinated and managed during project execution. In addition, a related question was the integration of dispersed development projects executed in many different geographic locations. According to the respondents, such projects suffer from lack of clarifications in terms of concepts, language, responsibilities and knowledge transfer.

5. Discussion: Struggling with integration

The idea of functional specialisation has been profound in engineering. However, our findings indicate of attempts to go in the opposite direction, i.e. towards integration, e.g. in the co-operation with customers and partners, between disciplines in more complex products, temporarily and geographically in cross-national development projects, in flattening the organisational structure, and in the design of the development process.

Even though the reported study has some obvious limitations (small sample, no direct observations of practices, only large, mature manufacturing companies, only companies based in Sweden, etc), it provides tentative directions for future examinations within the field of engineering management.

Hence assuming that the findings are generally valid, contemporary management of product development in mature companies seems to be characterised by complexity, diversity, and continuous problems with overlapping multiple interfaces. Due to a situation with increasing technical complexity, increasing service content in deliveries, dispersed project teams with members located at may different places, belonging to different organizational units or different legal entities on one hand, and a strong focus on lead time reduction on the other, present

engineering management seems to revolve around integration. There are demands for integration in many different dimensions, between different departments, between different competences, different simultaneous projects, and between successive projects drawing on the same resources.

Furthermore, there seem to be an increased tension between the efficient execution of development projects on short-term basis and the need for knowledge development and innovation on long-term basis in order to gain competitive advantages for the organization in the future. The difficulty for systematic competence development and reflective learning was further demonstrated and in all the companies, strategies for long-term sustainable conditions were lacking.

This struggle for integration raises an array of interesting issues for future research on engineering management. In the following, four examples as outlined.

5.1 Competence integration

A cornerstone in the discussion of integration is the ability for cross-functional co-operation, which is confirmed as of major importance for successful product development. One example is technology integration in products, exemplified by *mechatronic* solutions, which are becoming increasingly important in many industries. This highlights the needs for competence integration within development work, across traditional functional disciplines.

Another aspect of competence integration is the ability to work in *alliances*. The complexity of the development projects increases radically, with partners in different companies, with different cultural background, living in different time zones etc. Significant areas for further research are: competence integration between mechanical and software design, the process of R&D alliances and critical studies focusing on the efficiency of integration in different situations.

5.2 Process models for project integration

Engineering work is an abstract and social process needing common mental models as guidance to committed goals. Process models have been implemented with the purpose to support, manage and follow up the development work. The strength of such model is the simplification, which offers a common view. However, this simplification is also a weakness since it excludes opportunities for learning and experimentation

Furthermore, many companies have defined a common process model, heading for planning, structuring and time scheduling activities co-ordinating external partners. These process models are however company specific and the general models proposed by textbooks do usually not fit. Furthermore, companies' emphases the competence of judging when, how and why a process model should be used, modified, or further developed. An important area for research is to investigate and develop the understanding for content of structuring contra creativity in product development process models, and the possibility for relevant IT tools to support this processes.

5.3 Multi-project integration

Much of the research concerning project work, project management and project planning is based on the simplified situation with one single, on-going project with extensive resources available. As indicated above however, many contemporary engineering companies are dominated by a vast array of simultaneously and successive product development projects. In rela-

tion to single project situations, such multi-project settings raise different conditions for project execution, as well as for the organisation as a whole.

Projects are often used as a mechanism for cross-functional integration. However, when a significant share of the business hare carried out in projects (as in the studied organizations) there an additional need of cross-project coordination is created. How this should be done has been little explored. At present, there are a significant lack of concepts and theories for managing such complex, multi-project settings. There is a strong need for basic research on the nature of different kinds of multi-project settings under different contingencies and how they influence management, work processes and individuals.

Furthermore, projectification seems to produce problems with knowledge transfer between successive projects. However, this includes an interesting relationship between innovation and learning beyond the administrative problem of individuals' reluctance to fulfil tedious documentary tasks, or for that matter, to consult the documentation from earlier projects. At the individual level, the pleasures of innovating seem to exceed by far, the pleasures of consulting previous experiences. Thus, one of the most critical issues how to create long-term and sustainable knowledge processes within multi-project settings.

5.4 Leadership for integration of short-term and long-term perspectives

One of the most critical working conditions is leadership. Good leadership provides security, inspiration and commitment, while bad leadership can result in injustice, violation, unpredictability, conflicts, and power games. The respondents recognized the increasing importance of addressing "human problems" in R&D organizations. With today's time-pressure in product development, there is an obvious risk of depleting human resources, which means less sustainability for the organization in the long run. Thus the basic challenge is to create and maintain a high organizational commitment to both business success and human satisfaction and through high innovativeness in the long run.

One established distinction in personal leadership research is that between transformative and transactional leadership [26]. The latter have strong administrative elements and concerns maintenance of stability where change is incremental. Transformative leadership on the other hand is inspirational and often associated with drastic change and a drive for development. Development work requires stable conditions but also inspiration. Elements from both types of leadership seem to be needed and an important issue is what kind of leadership can create commitment that is not consuming and that enhances the innovative.

6. Concluding remarks

This article has discussed some of the most critical challenges for contemporary engineering management for gaining competitive advantages in the future. Today's development processes seems to have become too complex. The search for technical excellence in combination with resource efficiency tends result in extremely complex managerial tasks, with multiple dependencies and interfaces (of different kinds) to coordinate. Thus the primary challenge for engineering management is integration. First, at the organisational level there is an extensive need for multi-project integration, i.e. integration between the many simultaneous and successive projects hosted by the organisation over time. Secondly, a t the project level, there is a need for process integration, i.e. the integration between technical disciplines, organisational functions, etc in order to gain an effective product development process.

At the same time, existing theories and management models seem to overemphasizes short-term efficiency on the expense of long-term innovation and survival. The dominating focus is on one single project at a time, not on the long-term trajectories of technological development. This article have tried to outline some issues for future research in order to over-come theses anomalies.

However, the major research is still to be done. There is much more to learn from the practices of contemporary engineering management in order to develop the field. However, this requires close co-operation between academic scholars and industrial partners with own interests in improvement and learning. Consequently, a clinical research approach based on involvement and cooperation with actors in real-life companies seems instrumental for such knowledge development.

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