Manufacturing and supplier roles in product development

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Abstract

The increasingly competitive markets of the 1990s are generally perceived to be demanding higher-quality and higher-performing products, in shorter and more predictable development cycle-times, and at lower cost. Product development must therefore increasingly be managed as a concurrent, multi-disciplinary process. In terms of the manufacturing function and suppliers this is reflected in recommendations for the formal representation and active involvement of both manufacturing and suppliers on project teams, and a strategic approach to suppliers based on partnership sourcing arrangements and supplier development programmes. However, findings of a recent research study of the UK electrical and mechanical engineering sector, involving comparative analysis and benchmarking against a model of best practice of 12 in-depth case studies, followed by an interview survey of 46 companies, has shown that the diversity in the competitive environment and the characteristics of companies, their strategic policies, and their development projects, give rise to different requirements vis-à-vis the roles of manufacturing and suppliers in product innovation. Also, the study has shown that some features of ‘best-practice’ are inappropriate to some companies operating in the low-volume industries. It is concluded that, rather than adopt a prescriptive model of ‘best-practice’, companies need to develop procedures which more adequately reflect their inherent needs and the types of project they undertake. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Product development; Concurrent engineering; Best-practice; Low volume manufacturing; Company context

1. Introduction

Today, markets are generally perceived to be demanding higher-quality and higher-performing products, in shorter and more predictable development cycle-times, and at lower cost. A number of approaches to the effective management of product development have emerged in response to these pressures. Much of the development of this work has been instigated in the high-volume industries such as consumer electronics and automotive manufacture. In terms of the roles of manufacturing and suppliers this is reflected in recommendations for the formal representation and active involvement of both manufacturing and suppliers on project teams, and a strategic approach to suppliers which includes joint collaboration arrangements for product development. Many companies in the low-volume manufacturing industries are looking to implement many of these principles. However, developing products is a complex undertaking. Moreover, given the general characteristics of the
low-volume industries and the diverse range of factors which are unique to any one company, companies may find that these approaches are not easily implemented in their own context.

This paper briefly discusses the general assumptions concerning the competitive environment and best practice in product development. This includes the advances that have been made in the high-volume industries. The particular context and problems of the low-volume industries are then discussed, from which, the need for an approach which discriminates between both the general and context dependent features of product development practice is identified. Such an approach, it is argued, would provide as a means to address the problem of identifying the most appropriate practices for a company. A brief description of the research approach, involving 12 case studies and an interview survey of a further 46 companies, is given. Empirical evidence is then used to illustrate the way in which company and project contexts influence some features of the roles of manufacturing and suppliers in product development projects. This is followed by a discussion of the main conclusions.

2. General assumptions and best practice in product development

If the identification of a market opportunity or customer enquiry is to result in a successful product, then it is imperative that the product development process is efficiently and effectively managed. Reviewing the literature on product development (see for example [1–4] reveals a consensus in three main respects. First, markets are ever more competitive. There are increasing stringent demands for products having better quality, reliability and distinctive performance, in shorter and more reliable lead-times, and at reduced cost. Second, given these requirements, product development needs to be undertaken as a concurrent, multi-disciplinary activity. Third, a more concurrent and multi-disciplinary approach to the development of products may be achieved by establishing multi-disciplinary project teams, which maximise the use of enabling technologies such as rapid prototyping and cross-functional techniques such as quality function deployment (QFD), failure mode and effect analyses (FMEA), Design for Manufacture and Assembly (DFMA), etc. With regard to the role of manufacturing and suppliers this is reflected in recommendations for the formal representation and active involvement of both the manufacturing function and suppliers on project teams, and a strategic approach to suppliers based on partnership sourcing arrangements and supplier development programmes. These approaches, in combination, are frequently referred to as “best-practice”.

In practice, product development represents a complex challenge for many companies today. They must contend with an increasing number of product and process technologies. Moreover, external sourcing of technology and technological knowledge (in the form of products, processes and services) from suppliers and other providers is increasing [5] as a result of companies focusing in their core competences [6] and the need to be responsive to the changing and less predictable markets at both national and global scales [7]. In so far as representing a general trend, these factors expand the range of development options open to companies and increase the importance of the role of suppliers in the product development process.

These trends are most evident from examples and research studies of the high-volume sectors. In the automotive industry, for example, pressures to improve quality and reduce costs have been reflected in a move towards the development of lean production and supply, including a focus on improving the performance of suppliers and the relationships between the motor manufacturers and suppliers [8]. Against the general background of having fewer suppliers, tiered structures in the supply bases, just-in-time deliveries, TQM in supply chains, and supplier development and assessment programmes, this has involved the introduction of new forms of management and organisation to product development, including: the development of long-term relationships with suppliers based on inter-firm trust, joint programmes of continuous improvement and cost reduction, and an earlier involvement for suppliers in product technology and a greater responsibility for component specification and quality.
There is no doubt that many firms have benefited from trying to implement “best-practice” or have been encouraged to revise how they undertake the development of products. However, “best-practice” is heavily influenced by the practices of the high-volume industries – automotive and consumer electronics, for example – and the major “blue chip” manufacturers within these industries. It may be questioned whether these underlying philosophies and recommended practices are appropriate to all companies’ needs, in particular, companies operating in the low-volume manufacturing industries.

3. The context of the low-volume manufacturing industries

The low-volume industries cover a wide range of companies associated with capital goods and intermediate product markets. Their products tend to be manufactured for downstream industrial producers to use in the production of other goods and services, rather than for final or household markets. These range from large, complex, high-value capital goods (e.g. offshore structures, power generation plant, etc.) through to low-complexity intermediate products (e.g. pumps, valves, etc.) and are supplied to a range of industries (e.g. mechanical handling, power generation, oil exploration and recovery).

The characteristics of companies in the low-volume industries (i.e. organisation, products, markets, and so forth), their competitive environments and their range of strategic and operational choices, are both complex and diverse. Companies frequently serve, and have to be responsive to, a number of different markets – being subject to different competitive environments, and having different positions, roles and influences within supply chains, for example. Moreover, these supply chain structures, organisational roles and inter-firm relationships tend to be ephemeral, in some instances being limited to the duration of a specific project. A distinctive feature of the development of products in engineering companies is the need to manage various types of development project. These include contract projects where the product is developed to a customer’s particular requirements, and product development projects to develop a new or improved product either for sale as a standard item or customising to customers’ individual requirements.

The diversity of context in which products are developed will give rise to differing requirements and company practices vis-à-vis the roles of manufacturing and suppliers in product development. Interpreting the recommendations of “best-practice” in relation to the manufacturing and supplier roles inevitably represents a significant challenge to many companies. For example, in response to the increasingly competitive and changing environment many companies are looking consciously to apply approaches such as strategic partnering, product development and collaboration agreements with customers and suppliers, which are now common in the high-volume industries. However, the extent to which companies can commit resources to collaborative arrangements with their customers and suppliers can be conditioned by factors such as low product volumes, market instability and short project timescales. Therefore, it is apparent that an approach which is more sympathetic to, and allows for interpretation of, the general context and individual needs of companies operating in the low-volume industries is required.

4. Research approach

4.1. Contextual framework

The development and testing of a theoretical framework to explore the relationships between context and practice has been described in detail elsewhere [9]. The product development context is captured in terms of a company’s unique internal and external attributes (its organisation, markets, products, production process, suppliers, and the local and global environment), its strategic policies and the key features of specific projects. Product development practices are captured using a number of themes. In so far as the manufacturing and supplier roles are concerned these include both intra- and inter-firm processes and procedures. For any given company, the various features characterising the product development context interact with each other to establish particular requirements for product development. These requirements give rise to particular manufacturing and supplier roles.
4.2. Empirical work

The research findings presented in this paper are drawn from an empirical study involving 58 UK mechanical and electrical engineering companies engaged primarily in capital equipment and intermediate product markets [10]. The principal research aims were to identify generic and company specific features of engineering design and product development, and the extent to which recent recommended practices were embodied in companies’ product development practices and the constraints that may impede their adoption.

In-depth case studies, focusing on specific products and projects, were conducted in 12 UK engineering establishments. A comparative analysis of the case study information was undertaken. First, each of the case studies was assessed through a benchmarking exercise against the composite model of best practice derived from the literature to identify the levels of actual performance and the factors which constrained them from achieving best practice. Second, a thematic approach was adopted, whereby the variables used to classify companies, their strategic policies and project variables were systematically related to the features of the companies’ development practices. The comparative analysis resulted in a number of hypotheses concerning the adoption of best practice and the influence of attributes of the product development context on companies’ practices. These hypotheses were tested statistically for general applicability through an interview survey of a further 46 establishments.

The case study and survey companies ranged in size from 75 to 1000 employees, and included both independent and corporate establishments. They covered products of varying complexity, different types of market, both product development and contract projects, and varying degrees of product, production process, and market innovation.

5. Empirical findings

Empirical evidence, drawn from the aforementioned research, will now be used to illustrate the way in which company and project contexts were found to influence some features of the roles of manufacturing and suppliers in product development projects.

The general importance of manufacturing and supplier roles to the development projects studied was evidenced by the interview survey. Just over half of the projects studied had implications for the manufacturing process, with 68% of these involving the introduction of new equipment. Key supply items were identified in 80% of cases, of which 84% involved significant design requirements.

6. Project initiation and specification development

The initiation stages of projects are frequently cited as an area which is unsatisfactorily managed by companies [11]. An important feature of these concerns the development of specifications. Indeed, several sources, including The Corfield Report [12] and Walsh et al. [13] have identified specifications as being vital to success in product development. Moreover, in taking account of all the relevant considerations during the feasibility/tender development activities, including the formulation of the specification, best practice recommends that this should be a multi-disciplinary activity [4]. As might be expected, it was found that a greater range of functions were involved in the formulation of the specification in the case of projects requiring the integration of disciplines than those which did not. However, although key supply items were common, suppliers tended not to be involved in a formal manner. Similarly, the production departments were frequently not involved in the preparation of specifications when there were in fact manufacturing change implications. Moreover, production departments were sometimes involved when there were no manufacturing change implications. This suggested that, with 87% of companies having formal documented procedures for managing their development projects, production involvement was to some extent a reflection of companies’ general procedures and these were not adjusted to suit the needs of the specific project.
7. Organisation, process and inter-firm relationships during the main project stages

A key aspect of best practice concerns the requirement for product development to be undertaken as a concurrent, multi-disciplinary activity. This, it is claimed, requires the use of multi-disciplinary project teams, including the formal representation and close integration of the manufacturing function and suppliers. However, the research found that these recommendations were not generally applicable.

7.1. Project organisation

Companies were observed to use a number of different forms of project organisation (Table 1) and, moreover, the most appropriate choice of project organisation to adopt was found to be determined by the combined influences of several variables. In particular, the degree of integration required between functions and disciplines was found to be strong determinant of the type of project organisation adopted. The lower integration needs were found to be associated with functional and standard project management structures, while higher integration needs were associated with team-based project structures. Factors relating to the manufacturing and supplier dimensions, such as production process innovation\(^1\) and the supplier collaboration requirement,\(^2\) were postulated to be determinants of the form of project organisation adopted. Projects with a higher levels of production process innovation and a more pronounced supplier collaboration requirement were thought more likely to have a greater need for integration between the different functions and suppliers. Although the case studies suggested this to be the case, a significant relationship was not found in the survey – presumably reflecting the complex and multi-variate nature of the relationships involved.

7.2. Concurrency and inter-firm relationships

Simultaneous (or concurrent) engineering is a critical philosophy of best practice in product development. Some definitions of simultaneous engineering emphasise the simultaneous design of the product and the production process, see, for example, IDA [14]. However, focusing on the parallel activities of the engineering and manufacturing functions provides a rather narrow interpretation of simultaneous engineering, since the development of products usually involves other internal functions and external organisations. Most proponents of simultaneous engineering therefore seeks to encourage high levels of multidisciplinary involvement throughout the product development process [1,15,16]. Two aspects of simultaneous engineering were addressed by the research: first, the various formal inputs to the development process and, second, the levels of involvement of the different internal disciplines, customers and suppliers over the course of the development process (referred to here as concurrency).

The literature frequently emphasises the need for all the internal functions, as well as suppliers and customers, to be formally represented on projects. The need for formal representation on the project of the different functions was found to be related to the requirements for integration. Manufacturing, however, had formal project membership in 75% of cases in the survey, and this was closely related to

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\(^{1}\)Production process innovation was assessed as either no production process change (including minor tooling changes, etc.) or new production processes/new production equipment.

\(^{2}\)Supplier collaboration requirement was related to the existence and nature of key supply items. This was assessed by their existence, the design content, and whether the company and/or supplier were responsible for the design.
the complexity of the product, being rare for low-complexity products, and almost universal for high-complexity ones. Direct formal membership on project teams on the part of suppliers only occurred in two survey projects and never for customers, although there was often substantial involvement in particular project stages (see below).

As shown in Table 2, the involvement of the different internal disciplines, customers and suppliers over the course of the development process and, consequently, the aggregate levels of concurrency realised, varied widely between companies. Several characteristics of companies and their specific projects were found to be influential. In particular, concurrency was found to be higher when there was greater innovation in the product, when there was production process innovation involved, when projects had integrational requirements, and when project management and team-based structures were employed.

With regard to the individual disciplines, although the involvement of engineering was consistently high across all projects, the involvement of other disciplines, including manufacturing, was found to be variable. Manufacturing involvement throughout the project was greater for product development projects than contract projects, and when production process innovation (i.e. requiring the introduction of new manufacturing processes or equipment) was involved.

The extent of supplier involvement varied considerably, and was determined by the existence of key supply items, whether these involved significant design content and whether the company and/or supplier were responsible for the design. Indeed, the case studies illustrated how these were in turn conditional upon the general characteristics of, and strategic policies associated with, the supplier environment. A critical issue is that which relates to the strategically important make-or-buy decisions. Firstly, the internal span of processes determines the number of supply items. Secondly, there is the distinction between standard supply items and/or sub-contract processing requirements, and critical supply and/or sub-contract items which have significant impacts on design performance, costs, or involve particular processing skills, for example. These key supply items are a major determinant of the strategic importance of the supplier dimension and have most relevance to the opportunities to adopt the principles recommended by “best-practice”. Examples, drawn from the case studies, of factors constraining companies from adopting these principles include:

- Suppliers having particular competencies and/or limitations in their design or production processing capabilities. Consequently, faced with a requirement for stringent or specific capabilities, a company’s preferred choice of supplier may be limited.
- Key supply items being a customer specific requirement. Being dependent on the standardisation policies of a company’s respective customers, these key supply items become variable between contracts and, in effect, result in multi-sourcing requirements of a company.

Table 2
Summary statistics for concurrency measures*

<table>
<thead>
<tr>
<th>Concurrency measure</th>
<th>Mean</th>
<th>Median</th>
<th>Standard deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall concurrency</td>
<td>51.3</td>
<td>51</td>
<td>11.0</td>
<td>35</td>
<td>76</td>
</tr>
<tr>
<td>Marketing involvement</td>
<td>56.6</td>
<td>58</td>
<td>21.0</td>
<td>17</td>
<td>100</td>
</tr>
<tr>
<td>Engineering involvement</td>
<td>77.9</td>
<td>83</td>
<td>15.0</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Manufacturing involvement</td>
<td>48.3</td>
<td>50</td>
<td>19.1</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Purchasing involvement</td>
<td>31.0</td>
<td>33</td>
<td>17.9</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td>Supplier involvement</td>
<td>34.6</td>
<td>33</td>
<td>25.4</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td>Customer involvement</td>
<td>53.9</td>
<td>58</td>
<td>27.6</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

*Source: Interview survey.
Companies having a limited degree of influence over suppliers with strong market positions or for which they constitute a small part of the supplier’s business. This may, for example, require key pieces of supply equipment to be procured according to their availability within the project lead-time on a contract-by-contract basis, or may require a company to adopt an explicit policy of seeking alternative sources of supply to avoid being exposed to the potential risk of a supplier not performing or vacating the market.

It was also observed amongst the case studies that there were less opportunities for development collaboration with suppliers for companies operating in engineer-to-order and customised made-to-order markets than those operating in made-to-order and make-to-stock type markets. Essentially this reflected the more ephemeral or transitory nature of inter-firm roles and relationships with the former.

Therefore, given that several characteristics of companies and their specific projects were found to determine the involvement of manufacturing and suppliers (and, in turn, the aggregate measures of concurrency achieved) it is inappropriate to recommend “best-practice” levels of concurrency to which companies should aspire. It is more appropriate to seek the opportunities to implement the principles of best practice in the context of a specific company.

8. Production engineering considerations

The need to consider production engineering issues is of some relevance within the context of simultaneous engineering and the presumed need for development projects to focus on the “simultaneous design of the product and production process”. Many projects do not however involve significant production process innovation (i.e. new production equipment or processes) and it is therefore, appropriate to view production engineering considerations at two levels. The first of these concerns the design of the product to enable its effective manufacture within the constraints of the existing manufacturing processes. The second is a concern for more substantive issues relating to the design of the production process and its impact on the product’s design.

The extent and nature of the production engineering considerations were found to be strongly correlated with the degree of production process innovation involved in the project. In the case study projects, when there was no production process change involved, production considerations were usually limited to the product’s design features, whilst for production process changes concerns for the product-production process dimension were additionally introduced. The relationship between the type of design consideration and the production process innovation involved was also very strongly supported by the survey (see Table 3). Individual cases also suggested that high product complexity and deep product structure could involve implications relating to a product’s manufacture and assembly.

9. Development tools and techniques

Companies have been encouraged to adopt a number of tools and techniques which, in a concurrent and multi-disciplinary environment, will improve the integration and effectiveness of the development process. These include methods and techniques which facilitate cross-functional activities such as value engineering, quality function deployment, failure mode effect analysis, robust design, and brainstorming. Applied properly, these

<table>
<thead>
<tr>
<th>Production process innovation</th>
<th>Production engineering consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>% (N)</td>
<td></td>
</tr>
<tr>
<td>Product and process design</td>
<td>Design for manufacture</td>
</tr>
<tr>
<td>Yes</td>
<td>72 (18)</td>
</tr>
<tr>
<td>No</td>
<td>5 (1)</td>
</tr>
<tr>
<td>Total</td>
<td>43 (19)</td>
</tr>
</tbody>
</table>

*Source: Interview survey.
can enable a broad range of perspectives, including those of manufacturing and suppliers, to be introduced, thereby enabling a more effective focus on critical issues such as costs, quality, reliability, and so forth. There are also a range of modeling and analysis tools available to companies, including empirical methods, rig testing, physical models, CAE modeling and analysis, and rapid prototyping. In particular, developments in CAE modeling and analysis, and rapid prototyping are seen to offer many benefits to companies: more effective visualisation and interfacing between designers, manufacturing and suppliers, earlier analysis and improved ability to predict performance, reducing the need for manufacturing to produce expensive development prototypes, for example.

The research also found that many product development activities may be most effectively performed by the use of these cross-functional techniques and modeling and analysis tools. However, it was found that their use should be appropriate to the given situation. The survey indicated that cross-functional techniques activities (i.e. value engineering, quality function deployment, failure mode effect analysis, robust design, and brainstorming) were more frequently applied when there was a higher level of product innovation in the projects. Of the formal methods and techniques recommended by the best practice literature a number were not widely used by either the case study or survey companies – the degree of application of these amongst the survey projects is illustrated in Table 4. Significantly, some of these, including quality function deployment and robust design, were not widely known, let alone applied.

CAE modeling and analysis tools were used in 54% of the survey projects, particularly those involving high levels of innovation and complex products, although they were used in other types of project as well. The case studies demonstrated that the use of design modeling and analysis tools (i.e empirical methods, rig testing, physical models, CAE modeling and analysis, and rapid prototyping) during the initial design stages was frequently associated with lead-time pressures, high product complexity and deep product structure (related, for example, to costs and constraints on prototyping in specific cases) and, in association with these, an emphasis on reliability and technical performance. These were reflected in the need to be able adequately to predict product performance early in the design process. However, this pattern was not borne out by the survey, suggesting that there may be scope for improvement here.

**Table 4**  
Application of cross-functional techniques and modeling and analysis tools*

<table>
<thead>
<tr>
<th>No.</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-functional techniques</td>
<td></td>
</tr>
<tr>
<td>Value engineering</td>
<td>29</td>
</tr>
<tr>
<td>FMEA/root cause analysis</td>
<td>20</td>
</tr>
<tr>
<td>Quality function deployment</td>
<td>6</td>
</tr>
<tr>
<td>Robust design/Taguchi</td>
<td>6</td>
</tr>
<tr>
<td>Modeling &amp; analysis tools</td>
<td></td>
</tr>
<tr>
<td>Rig testing</td>
<td>32</td>
</tr>
<tr>
<td>CAE modeling &amp; analysis</td>
<td>25</td>
</tr>
<tr>
<td>Physical models</td>
<td>21</td>
</tr>
<tr>
<td>Rapid prototyping</td>
<td>10</td>
</tr>
</tbody>
</table>

*Source: Interview survey.

10. Conclusions

The characteristics of the low-volume industries and the problems faced by companies when developing their products has been explored in this paper from the perspective of the roles of manufacturing and suppliers. By adopting an approach which enables the identification of both the general and context dependent features of the processes by which products are developed in engineering companies, it has been shown that some aspects of what is often termed “best-practice” in product development are not appropriate to certain company and project contexts. This is not to imply that there is anything wrong with the adoption of a multidisciplinary and highly concurrent approach per se – this is an appropriate response to a competitive environment subject to significant pressures on costs, lead-times and quality.

The research has shown that the appropriate organisational, process and other mechanisms relating to the roles and interfaces of manufacturing
and suppliers are determined by a range of contextual factors, not least of which are the characteristics of individual projects. Therefore, rather than adopt a model of “best-practice”, companies need to develop procedures which more adequately reflect their inherent needs and the types of project they undertake. It is also important that, having developed their general procedures, companies modify these to suit the requirements of individual projects and apply suitable metrics to enable continuous improvements.

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