



Innovation in product development within the electronics industry

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Abstract

The authors present a framework which describes the intensity of application of the main product development techniques and methodologies (grouped into six classes) in relation to some project complexity variables (product specification, product complexity and project scope). The framework is tested using a case-study approach: four successful firms belonging to the electronics industry are examined with respect to the product development techniques adopted. The proposed framework provides a tool for checking the effectiveness of the main product development techniques in different situations. © 1999 Elsevier Science Ltd. All rights reserved.

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1. Introduction

The growing importance of product development, in terms of timeliness and investments in the area of product design and engineering, induces companies to evaluate the advantages of using (whether in combination or not) different techniques and methodologies (Wheelwright and Clark, 1992; Maylor, 1997). While there is quite a vast amount of literature dealing with the impact of certain techniques on product development performance (Cusumano and Nobeoka, 1992; Brown and Eisenhardt, 1995), there are relatively few studies concerning the applicability of these techniques depending upon project complexity. This paper examines the spheres where the main techniques and methodologies of product development can be applied in relation to different variables, such as:

- the product specification origin;
- the complexity of the product;
- the scope of the project.

In our analysis, the product specification origin (made by customers or in-house) is the first dimension of project complexity. The other dimensions are the product

complexity and project scope of Clark and Fujimoto (1991).

According to the classification worked out by Clark and Fujimoto (1991), the complexity of the product and the range of the project are, respectively, considered as: *variety* (product range as number of product configurations, to which the concept of mix flexibility (De Toni and Tonchia, 1998) is related) and *degree of product innovation* (new parts and new processes required); *number of parts in common* (with present models measured by the 'common parts ratio' or 'commonality index' (Vakharia et al., 1996), and with old products measured by the 'carried-over parts ratio' or 'carry-over index') and *level of involvement of the suppliers in the project* (suppliers' share of engineering effort).

A theoretical framework was constructed and it is suggested that this can be used for describing the intensity of application of the product development techniques in relation to the project complexity variables considered (the product specification origin, the complexity of the product, the scope of the project).

The investigative analysis carried out refers to the electronics industry, of particular interest because product development activities are critical for the achievement of competitive success and require large investments to be made (Loch et al., 1996; Terwiesch et al., 1998).

Four successful case studies were examined, with the purpose of setting up the framework further. The refer-

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ence framework, by means of which the successful case studies were examined, represents a tool for checking the effectiveness of the main product development techniques and methodologies in relation to specific situations.

2. Product development techniques

The more widespread product development techniques and methodologies are grouped into six classes, according to their own purposes:

1. design performance improvement by external contributions—*early supplier involvement (ESI)*;
2. part number reduction—*variety reduction program (VRP)* and *modularization (Mod)*;
3. manufacturability and assemblability—*design for manufacturing (DFM)* and *design for assembly (DFA)*;
4. project schedule and development time reduction—*work breakdown structure (WBS)* and *overlapping (OL)*;
5. product assessment—*design of experiments (DOE)*, *early problem detector prototyping (EPDP)*, *failure mode effect analysis (FMEA)*;
6. customer satisfaction—*quality function deployment (QFD)* and *value engineering (VE)*.

These techniques have been collocated along the operational value chain (Fig. 1), delineating—for each technique—the functions and the departments of the company involved and the upstream and downstream relationships with the suppliers and the customers.

The ESI simultaneously involves the design and purchasing functions and the suppliers. Specularly QFD/VE involve the design and marketing functions and the customers. The VRP/Mod regard the design function, while DFM/DFA regard both design and production, as do the WBS/OL and the DOE/EPDP/FMEA, techniques which, respectively, regard the programming of the activities of the two functions and the testing/review of the project specifications given by the design function to the production function.

2.1. Early supplier involvement (ESI)

The ESI, a part of the supplier involvement level into the project (high or low), exploits the important role that the supplier can play from the beginning of the product development process (Clark and Fujimoto, 1991; Dowlatshahi, 1992). Several studies and empirical observations have demonstrated the benefits of collaborating with the suppliers at the product/process design and development stages (Clark, 1989; Fujimoto, 1997; De Toni and Nassimbeni, 1999). The contribution of the supplier in new product development can, in fact, enable the buyer:

- to capitalise on the source's expertise within a certain application horizon. The supplier can make an important contribution to the activity of material selection, the setting up of the productive processes, the reduction of the number of components, etc.;
- to shorten the time-to-market. When the supplier is a member of the new product development team, he gains a more complete understanding of the buyer's requirements and problems. At the same time, supplier processing constraints and capabilities can be considered by the buyer's design personnel (O'Neal, 1993);
- to improve the quality and lower the global cost. Here problems often arise from the lack of consideration, on the part of the buyer firm designers, of the productive and technological capacity of the suppliers. A significant portion of the quality and costs of the product is decided at the initial phases of the product development process, which also include the choice of materials and the corresponding choice of the sources. The supplier's technical competence can allow the reduction of the manufacturing costs by designing a product to fit better the manufacturing processes employed by both firms;
- to increase the level of motivation and responsibility of suppliers, thanks to their 'ownership' of the total product design and not just 'pieces' of it.

Various investigations have shown that one of the principal reasons for the competitive advantage of the

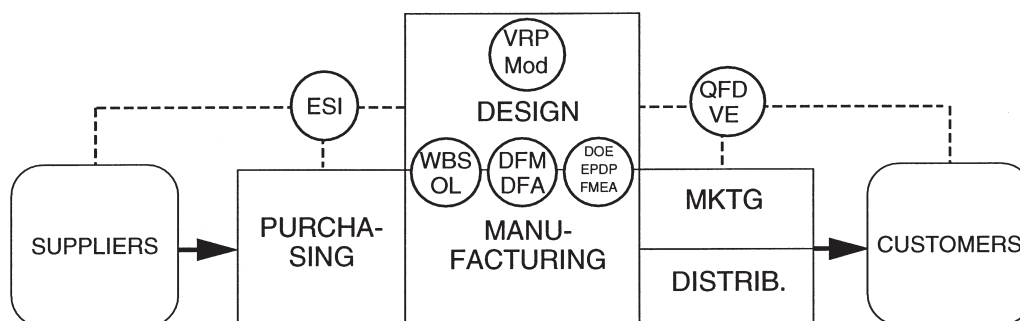


Fig. 1. The product development techniques along the operational value chain.

Japanese automotive industry can be found in their original supply system (Fruin, 1992; Nishiguchi, 1994; Liker, 1995). The Japanese assemblers actively involve the suppliers in new product development activities asking for their contribution on almost all the technological aspects of the product. The sharing of design responsibility and the exchange of information concerning the product has enabled the assemblers to improve time, cost, and quality performance significantly (Ragatz et al., 1997). Following the performance of their Japanese competitors, the European automobile makers have imported the co-design approach: the research carried out by Lamming (1990); Turnbull et al. (1992) indicate that in the European automotive industry the involvement of the supplier in new product development has become frequent.

2.2. Variety reduction program (VRP) and modularization (Mod)

The VRP is a technique, theorised by Koudate and Suzue (1990), which aims at reducing design and product development costs by reducing the number of parts and the processes needed to manufacture a product, while at the same time responding to the market request for a high variety of products.

Among the programs for reducing variety, 'modularization' or modular type design (Rajput and Bennett, 1989; De Toni and Zipponi, 1991) has its own place. With this method, products that are sufficiently differentiated can be obtained, together with economy in the activities of design, production and management of logistic flows, thanks to the repetitive use of modules and parts that are standard in the definition of the product.

The attempt to look for variety only in the 'upper part' of the bill of materials ('end-stage differentiation', that is, in the last stages of assembly of the finished product) is also known as the 'mushroom concept' (Mather, 1988).

2.3. Design for manufacturability (DFM) and design for assembly (DFA)

The DFM (Youssef, 1994) takes into consideration the effects of product structure on manufacturing costs and 'producibility' (Wheelwright and Clark, 1992). Benefiting from a collaborative approach between the design and production functions, it aims at the simplification of the productive processes, characteristics and performances of the product being equal (Stoll, 1988; Niebel and Liu, 1992).

Similarly, the DFA (Boothroyd and Dewhurst, 1987) is proposed as a means of containing set-up costs while maintaining the high quality of the installation by means of an appropriate choice of the methods of assembly, reduction in movements and directions of assembly, the

installation and link of the components associated with form, materials and technology etc.

Exactly because of the impact that certain design choices have on production this is also known as 'design for operations' (DFO) (Schonberger, 1990).

2.4. Work breakdown structure (WBS) and overlapping (OL)

Product development adopts some engineering project management techniques, such as PERT (Program Evaluation and Review Technique) for sequencing and scheduling the activities. PERT is applied to WBS, which describes the activities needed to complete a product. The WBS is, in its turn, derived from the PFS (Product Function Structure) and the PBS (Product Breakdown Structure) which define, respectively, the functionality of a product and its bill of materials (Koudate, 1990).

The time scheduling outlined by applying PERT to WBS can, however, also permit compression of product development times by overlapping the stages: concept generation, product planning, product design, product engineering, process engineering, prototyping and pilot testing, production ramp-up, series production. Overlapping concerns the early involvement of the downward teams and is measured by the 'simultaneity ratio' (Clark and Fujimoto, 1991).

By several authors the overlapping concept is associated with that of 'simultaneous engineering' (SE) (or 'concurrent engineering'; CE) (Nevins and Whitney, 1989), but this latter has acquired different and broader meanings in the literature, often going beyond the original meaning (Trygg, 1992).

2.5. Design of experiments (DOE), early problem detector prototyping (EPDP), failure mode effect analysis (FMEA)

The possibility of completely and rapidly evaluating the implications and consequences of a certain design choice is fundamental both for achieving a high product reliability and for containing the costs due to the project changeovers, which may become more expensive the nearer they are to the productive stage. Among the techniques for the so-called 'reverse' (or 'feed-back') engineering (Ettlie and Stoll, 1990), the following are worth noting: the design of experiments (DOE), the early problem detector prototyping (EPDP) and the failure mode effect analysis (FMEA).

Using the DOE, the physical and operative parameters which most influence a characteristic or performance of the product can be determined (Wang et al., 1992). Thus a model is sought that joins these parameters to the results and individually varies the parameters to evaluate the impact. Test sets and experimental schemes are defined.

The EPDP uses prototypes to draw attention as soon as possible to problems that may arise and functional defects correlated to the design choices. The prototypes can closely resemble the final product or can only represent some of its functions, which must be tested individually ('step-by-step prototyping' (Clark and Fujimoto, 1991)).

The FMEA is a technique for evaluating product reliability. The FMEA considers the possible failure modes (of the whole product and thus the general functionality, or of one of its parts), the effects and the causes that led to the break-down, and if it is due to materials or processes.

2.6. Quality function deployment (QFD) and value engineering (VE)

Among the techniques for the management of the design–marketing interface (Dowlatshahi, 1993; Ettlie, 1997), we consider quality function deployment (QFD) and value engineering (VE).

The QFD is a methodology which originated in Japan at the end of the 1960s. Its aim is to translate the customers' requirements into technical specifications according to a priority scale that has been drawn up using even information on competing products. This methodology was formalised by Akao (1990) and can be summarised in the 'what–how' matrix.

The VE consists of the study of the functional relationship between performance and cost of a product. The VE refers to the product development phases, while the value analysis (VA) refers to an already existing product (DeMarle and Shillito, 1992). The VE is a method of reducing costs by means of the definition of the 'value' of the products and their parts, given by the ratio between 'function' and 'cost'. Function by function and component by component, the VE considers the materials to be used and the work to be carried out, choosing which ones on the basis of effectiveness in carrying out the function and their costs.

3. Relationships between product development techniques and project complexity

In this section the hypothesised relationships between *product development techniques* (grouped into the preceding six classes) and the *project complexity variables* (*product specification origin*, *product complexity* in terms of *variety* and *innovation degree*, *project scope* in terms of *commonality*, *carry-over* and *supplier involvement*) are presented; they are synthesised in Fig. 2. These hypotheses refer to the intensity of the link between each technique and each variable, considered individually.

3.1. Early supply involvement (ESI) and project complexity

3.1.1. Product specification

In the companies in which the product specifications are made by the customer (from here on PSBC), the subcontractors generally intervene only after the detailed design developed by the main contractor. Involvement, when it does take place, is at a stage that is distant from the product concept. Vice versa, in the companies in which the product specifications are made in-house (PSIH), the influence of the supplied materials on costs, on producibility and on time-to-market encourages the involvement of suppliers right from the initial stages.

3.1.2. Variety

This is unpredictable. The increase in the production mix seems to increase the need for the early involvement of suppliers only in the cases of more intensive utilisation of modularised and standardised intermediate components (hourglass concept). For these parts the greater production volumes and critical state (parts that are used in more than one product) make it advisable for the suppliers to be involved right from the initial stages of product development. If the variety is achieved without the use of modular parts that are common to a number of products, then possibly the involvement of the suppliers is not required right from the first stages of product development.

3.1.3. Innovation

The early involvement of external sources can enable the company to individualise more quickly and more efficiently incorporate the product and process innovation, since suppliers are often an important vehicle of innovation.

3.1.4. Commonality and carry-over

The early involvement of suppliers becomes more critical as the commonality and carry-over ratio lowers, that is how much lower is the recourse to components whose production is already consolidated.

3.1.5. Supplier involvement

The early involvement of the suppliers becomes more important the greater is the absolute level of their contribution. In fact it can allow a better material selection, the definition of project specificity that responds more exactly to the needs of the productive process, the quality improvement of the product, the reduction in the number of components, the reduction in the global costs and in the time-to-market.

3.2. Variety reduction program (VRP) and modularization (Mod) and project complexity

3.2.1. Product specification

In the PSBC companies it is not so advantageous to attain the definition of standard modules and the reduction in the number of components. In the PSIH companies the reduction in the components is especially justified for cost reasons (a higher productive volume) while modularization enables the firm to withstand more effectively the uncertainties of demand.

3.2.2. Variety

The need for differentiation and diversification in products can result in the firm having an unbearable number of codes to manage. In this context, the reduction in the number of components and the identification of modules that are common to a greater number of models, can reduce the costs and simplify the managerial burden while still maintaining the product's high number of final configurations.

3.2.3. Innovation

This is unpredictable. The choice to reduce the number of components and to use modularization seems to be independent of the level of innovation incorporated into the product and the process.

3.2.4. Commonality and carry-over

When there is a high rate of recovery of already used parts, the need for VRP and modularization is not so great. But where commonality and carry-over are low, the techniques in question help to keep the proliferation of design techniques and components under control.

3.2.5. Supplier involvement

Recourse to the reduction in the number of components and modularization increases the productive volume of some parts and thus creates the conditions for a closer collaborative link with those suppliers that contribute to the manufacturing of those parts. The reduction in the number of components, when it reduces the number of components bought outside, lowers the number of suppliers to the advantage of economy in supply management.

3.3. Design for manufacturability (DFM) and design for assembly (DFA) and project complexity

3.3.1. Product specification

The techniques considered appear more suited to productive contexts that are entirely PSIH: the greater stability of the productive configuration due to a higher volume makes it advisable to pay more attention to manufacturability and assemblability of the product. Such efforts cannot be justified in connection with basi-

cally lower volumes of production (PSBC), as the productive process is more flexible.

3.3.2. Variety

This is unpredictable. Under the same conditions of total productive volume, two situations must be distinguished:

- variety is attained by increasing the number of planned and produced components. In this case the analysis of manufacturability and assemblability is not worth whole as it is applied to parts characterised by a low productive volume;
- variety is attained by a more extensive use of modular parts. In this case the more critical state and greater productive volume associated with those parts can make it convenient to use the techniques in question.

3.3.3. Innovation

This is unpredictable. The techniques in question seem to be of use independently of the level of innovation incorporated into the product as, in any case, they improve the costs and time-to-market of the new product.

3.3.4. Commonality and carry-over

A large recourse to old components justifies the use of the techniques in question as the efforts to improve manufacturability and assemblability can focus on a lower number of components and sub-units.

3.3.5. Supplier involvement

The amount of suppliers' involvement appears to be independent of the application of the techniques in question.

3.4. Work breakdown structure (WBS) and overlapping (OL) and project complexity

3.4.1. Product specification

This is unpredictable. In PSBC firms the co-ordination and planning of the specialised contributions made from outside are variables that are critical to success. Analogously the PSIH firms typically have longer product development times. Thus, they need adequate tools for scheduling and compressing the times of product development.

3.4.2. Variety

As variety increases the project commitments of the firm extend (a greater number of products) and become more complex (problems of allocation and scheduling resources distributed over a number of products). So there is an increase in the need to structure the planning activities rigidly and search for as much overlapping as possible.

3.4.3. Innovation

The need for a precise structuring of the activities and the utilisation of overlapping become greater when the innovative content incorporated into the product increases. In fact, innovation is generally the result of interfunctional and interdisciplinary contributions and lengthens the product development time (with a more rigorous need for scheduling and overlapping).

3.4.4. Commonality and carry-over

The less the commonality and carry-over, the greater is the workload of the product development departments. The need for the timely scheduling of the activities thus grows as commonality and carry-over decrease.

3.4.5. Supplier involvement

Planning the intervention of outside suppliers is often difficult and complex. However, the need for scheduling and overlapping can lead to a drastic reduction in times and a greater respect for delivery dates, especially in those productive contexts which more often make recourse to the contribution of outside suppliers.

3.5. Design of experiments (DOE), early problem detector prototyping (EPDP), failure mode effect analysis (FMEA) and project complexity

3.5.1. Product specification

The identification of the technical and functional problems appears to be more critical in the contexts that operate on forecasting (PSIH) where the productive volumes tend to be higher and the productive process more rigid and dedicated.

3.5.2. Variety

This is unpredictable. Under the same conditions of total productive volume, also in this case a distinction must be drawn between two situations:

- variety is obtained by increasing the number of components to be planned and produced. In this case the application of the techniques under consideration is not advantageous as it is applied to parts characterised by a low productive volume;
- variety is obtained by means of a more extensive use of modular parts. In this case the greater criticality and larger productive volumes associated with those parts make the use of the technique in question worthwhile.

3.5.3. Innovation

The greater the innovative content incorporated into the finished product, the greater is the need to single out merits and defects of the materials, functional problems of the components and lack of quality and trustworthiness of the parts.

3.5.4. Commonality and carry-over

If the commonality and carry-over are low, the extensive replacement of components hinders the proper focusing of the technique involved. If the commonality and carry-over are high the greater temporal stability in the mix of the bill of material and components makes it advisable to examine accurately the recurring parts.

3.5.5. Supplier involvement

The use of the techniques in question seems to be independent of the importance of supplier involvement since they are already targeted at improving the quality and reliability of the product.

3.6. Quality function deployment (QFD), value engineering (VE) and project complexity

3.6.1. Product specification

The use of QFD appears to be more critical in PSIH firms which do not relate directly to the customer and so must interpret and forecast his tastes. In the PSBC firms instead, contact and comparison with the customer accompany the project right from the product concept. Also value engineering is more advantageous in PSIH contexts: the repeatability of these productions makes it advisable to carry out a more accurate examination of the cost/value ratio of every component manufactured and assembled.

3.6.2. Variety

This is unpredictable. The techniques in question improve customer satisfaction and the cost/values ratio of each product, elements that are critical independently of the level of product variety.

3.6.3. Innovation

A technologically innovative product requires a detailed analysis of the value/cost of its elements, its functional contents and the value perceived by the customer. Competitive contexts that are passing through a rapid technological evolution require particular sensitivity to the actual expectations of the customer and a careful evaluation of the costs of the new products.

3.6.4. Commonality and carry-over

The lower the carry-over and commonality, the greater is the need for an accurate examination to verify whether it is in agreement with the customers' expectations and its cost/value ratio.

3.6.5. Supplier involvement

The use of the techniques in question appears to be advisable independently of the amount of recourse to outside (see Fig. 2).

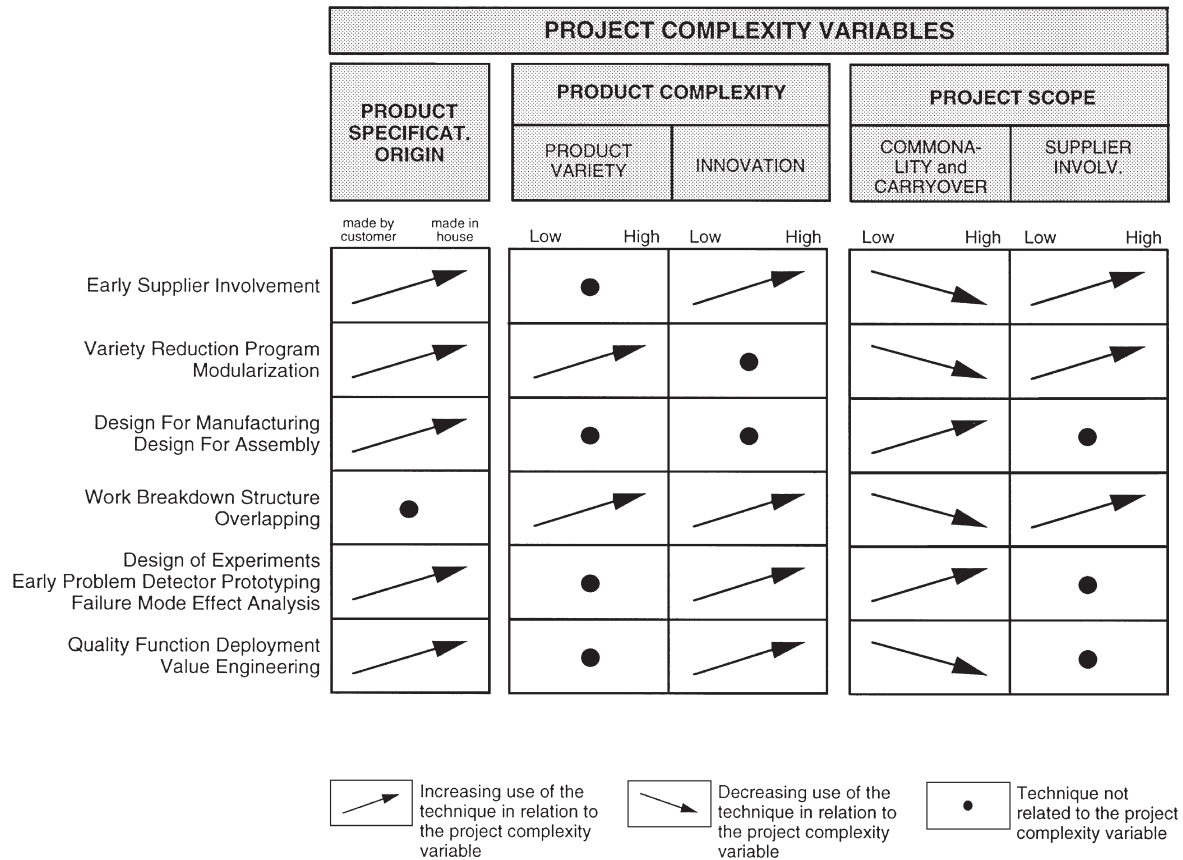


Fig. 2. The hypothesised relations between product development techniques and project complexity variables.

4. Case studies examination

Four electronic companies have been singled out that are characterised by different product specifications, product complexity, project scope. These four companies were investigated to determine the nature and intensity of the use of the product development techniques adopted. The companies are briefly introduced in Table 1. They present a wide range of situations concerning the project complexity variables: for two of them the product specifications are made by the customers while for the others they are made in-house; the product complexity (in terms of product variety and innovation degree) is both high and low in the four cases; also the project scope (in terms of commonality/carry-over and supplier involvement) is different in the four cases.

In the following section comments are made on the hypothesised relationships in the light of empirical evidence gathered from the case studies analysed.

4.1. Early supplier involvement (ESI)

The hypothesised more extensive use of these techniques in contexts in which the commonality and carry-over ratio is low and the product specifications are made in-house is confirmed by the cases examined. In Case 1,

for example, the high technical complexity and innovation requirements of the market demand hinder the achievement of commonalities and carry-over, promoting the early involvement of the suppliers in order timely to identify innovative components and materials and to shorten the time-to-market.

As foreseen from the model, the cases seem to exclude the possibility of a direct link between product variability and intensity of resort to ESI. Finally the cases do not suggest that there is a relationship between the 'when' (early) and the 'how much' the suppliers are involved in product development, while the proposed model suggests that there is a direct proportional link.

4.2. Variety reduction program (VRP) and modularization (Mod)

The hypothesised more widespread use of these techniques in contexts in which the commonality and carry-over ratio is lower and the product specifications are made in-house was confirmed by the cases examined. In relation to the product variety, the theoretical trend is contradictory only in Case 3, in which scarce use is made of the techniques even in presence of high productive variety. In this firm, the standardisation and the modularization effort can involve only a few product models.

Table 1
The case-study firms

Case 1.	<p>Turnover: 66 milliard lire; employees: 228. Main products: electronic cards; automotive electronic systems for the supervision of plants for working metals. Product specification: PSBC. Variety: low. The company concentrates on a few basic products which are then modified and adapted to the needs of the customer. Innovation: high. The innovation incorporated into the product is the principal element of differentiation. Commonality and carry-over: low. The technical complexity and the almost complete absence of repetition limits carry-over. Supplier involvement: high. The company is strongly decentralised and makes ample use of outside know-how.</p>
Case 2.	<p>Turnover: 59 milliards lire; employees: 303. Main products: electronic clocks and clocking-in systems. Product specification: PSBC. Variety: low. The range of products is limited, mainly on account of the reduced size of the market. Innovation: high. The company is continuously searching for reliable products characterised by a high technological content. Commonality and carry-over: high. Time-to-market and costs are strongly linked to the possibility of recycling already made components. Supplier involvement: low. The presence of few leaders (relative to the strategic codes, oligopoly market) has up to now prevented the company from having collaborative relations with the suppliers.</p>
Case 3.	<p>Turnover: 49 milliards lire; employees: 99. Main products: didactic electronic instruments. Product specification: PSIH. Variety: high. The demand is naturally varied and thus imposes the control of various applications and technologies on the firm. Innovation: low. Innovation is not endogenous but rather incorporated from the outside. Commonality and carry-over: low. The variability in demand and the need to offer the market a highly customised product reduces carry-over. Supplier involvement: high. The company frequently requires the development and production of specific parts from the outside.</p>
Case 4.	<p>Turnover: 318 milliards lire; employees: 1251. Main products: television sets and video recorders. Product specification: PSIH. Variety: high. The market requires the availability of a high number of models. Innovation: high. The sectors in which this company works are characterised by the rapid and frequent introduction of technologically innovative products. Commonality and carry-over: high. Electronic cards and components lends itself to re-utilisation in several models. Supplier involvement: low. The control of information in the supply market and the ability to acquire innovations wherever they are made appears to be more important than the involvement of suppliers.</p>

These standards usually interest the dimensions and the electrical characteristic of the components, while modularization regards electrical and electronical cards and panels. Interesting is also in the standardisation efforts carried out by Case 1. Here the firm has developed a process control system consisting of one standard base (the interfacing card to a PC) and one part engineered on the customer's specifications (the network of detectors to dislocate along the process).

In accordance with the hypothesis, the cases appear to exclude a direct link between the techniques and the product and process innovation. The cases do not seem to confirm a link between the techniques considered and the amount of supplier involvement: the applicability of the techniques do not seem to be linked to the level of design and productive externalisation.

4.3. Design for manufacturability (DFM) and design for assembly (DFA)

The hypothesised more extended use of these techniques in contexts where the commonality and carry-over ratio is higher and the product specifications are

made in-house is confirmed by the cases examined. In accordance with the hypothesis the cases appear to exclude a direct link between the techniques considered, the product variability and the product and process innovation. Instead the cases seem to suggest that there is an inversely proportional relationship between the intensity of the use of the considered techniques and the importance of supplier involvement: in Cases 2 and 4 there is a low amount of use of these techniques and a low amount of supplier involvement, in Cases 1 and 3 the opposite occurs. In these latter cases, already in the first phases of new product development, a particular attention to product manufacturability and assembly arise, above all when products are expected to reach high production volumes.

4.4. Work breakdown structure (WBS) and overlapping (OL)

The hypothesised more intense application of WBS and OL techniques in contexts characterised by greater variety, a lower carry-over ratio and greater supplier

involvement is confirmed by the empirical evidence, as is the lack of a direct link with the product specifications.

For example, in Case 3, the more complex activities, due to a great variety, low carry-over and frequent involvement of the suppliers also for the development of specific parts, led to a wider use of the planning instruments, such as WBS and CPM/PERT.

Instead the most intense use of these techniques in more innovative contexts, suggested by the theoretical model, was not so well demonstrated in the cases, which would seem to suggest the lack of a direct link.

4.5. Design of experiments (DOE), early problem detector prototyping (EPDP), failure mode effect analysis (FMEA)

The hypothesised more intense application of these techniques in contexts characterised by greater amounts of innovation and a higher 'carry-over' ratio proposed in the theoretical model is confirmed by the cases.

In Case 4 (a video equipment producer) the continuously changing technological content together with the growing importance of quality require a detail analysis of the functional problems and an accurate study of the failure effects. The warranty costs for this type of product are in fact very high. Instead, Case 2 well supports the thesis that, if the commonality and carry-over are high, the review engineering, especially the DOE technique, is facilitated: in the electronic clocks sector, in fact, several components are recycled and this permits a longer period of testing.

There is not a strong link between the use of the techniques and the product specification origin, while as far as involvement of the suppliers is concerned, the empirical evidence (except for Case 1) shows a greater use of the techniques in the presence of low supplier involvement.

4.6. Quality function deployment (QFD) and value engineering (VE)

The cases confirm the trends shown by the theoretical model regarding the degree of innovation, the carry-over ratio and the product specifications origin. The lack of a link between the use of these techniques and the variety of the products and supplier involvement, respectively, is also confirmed.

The innovation degree seems to be the most influential variable for the use of QFD/VE techniques. In Case 4 there has been noted a strong use of these techniques, due to product specifications necessarily made in-house and the most innovative context among the firms examined, although the carry-over ratio is low.

Briefly, not all the relations hypothesised by the model were confirmed on an empirical level. The disagreement

between the hypothesised relations and those checked empirically could be due to:

- the specificity of the company concerned;
- the combined action of two or more project complexity variables on each technique;
- the inadequacy of the model.

5. Conclusions

In the present context, characterised by increasingly aggressive global competition, higher costs for research and development of new products, technologies in rapid evolution, competitive success depends more and more on product development. Thus, the competitive necessity to shorten the product-life, to enhance the frequency of new product launches, and the need to incorporate into new products a higher content of technology have promoted a quick diffusion of advanced techniques for product development management in many firms. The benefits of these techniques can be several: a reduction in overall development costs and time, an improvement in product quality, the possibility of incorporating innovations suggested by the supplier, and higher consistency with customer's expectations. However, the proper use of most of the advanced product development techniques is related to several industry- and firm-specific factors, in particular, the project complexity.

In this paper the authors propose a theoretical framework concerning the hypothesised relations between the main product development techniques and some project complexity variables: product specification, product complexity and project scope. The theoretical framework was tested on four successful case studies in the electronics industry, and showed agreements and disagreements in respect to the hypothesised relations. Even if this framework needs to be further verified through an extensive survey on a numerically adequate sample, the proposed framework can provide practitioners and theorists with tools for the identification of the context best suited for the main product development techniques and methodologies.

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manufacturing practices and performances, and logistics.



include supply chain management, strategic purchasing, lean production and logistics.



manufacturing strategy, and performance management and measurement.

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