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2nd INTERNATIONAL PRODUCT DEVELOPMENT MANAGEMENT CONFERENCE ON NEW APPROACHES TO DEVELOPMENT AND ENGINEERING

Gothenburg, Sweden, May 30-31, 1994

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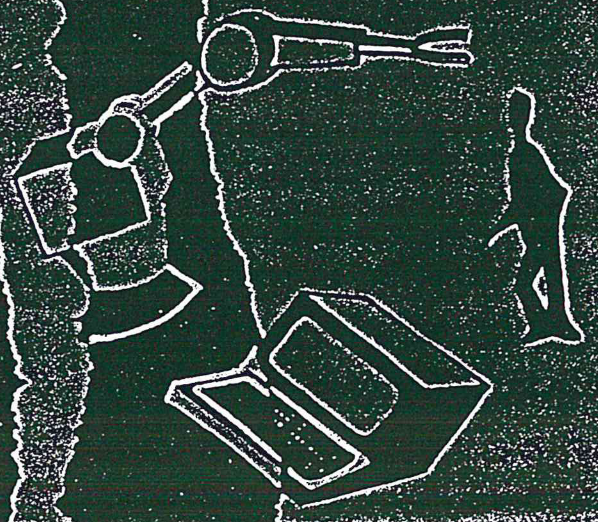

Part 1 (2)

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APPENDIX: Variables in the Least Squares Dummy Variable Model

VARIABLE NAME	EXPLANATION
	DEPENDENT VARIABLES
Innovative output	Cumulative number of publications an organization has produced up to a given year of observation.
Market share	Cumulative number of publications an organization has produced up to a given year divided by the cumulative number of publications produced by all organizations still active that year.
	CONTROL VARIABLES AT COMMUNITY LEVEL
Number of publications	Cumulative number of publications each year of observation.
Herfindahl index	Herfindahl index of concentration of researchers among the various research organizations.
Density	Number of organizations active in the technological community [27].
Density^2/1000	Number of organizations^2/1000. I.e. contemporaneous density measure [27].
Percentage of connected organizations	The number of organizations connected to each other ('clique') divided by the total number of organizations active in the field each year of observation.
	COOPERATIVE RESEARCH CO-VARIATES AT ORGANIZATIONAL LEVEL
Relative collaborative position	The number of collaborations each organization is involved in divided by the number of collaborations of the organization cooperating most in a given year.
Ratio collaborative output to total output	The cumulative number of publications which result from cooperative research divided by the total cumulative number of publications for each organization in the dataset. Range: 0 = all publications result from in-house research activities - to - 1 = all publications are the result of collaborative efforts.
Prestige	This variable is an indicator of the prestige position of each organization relative to the most prestigious organization in the dataset. The absolute prestige position for each organization is computed according to Burt [4]. This absolute value for each organization is then divided by the prestige value of the most prestigious organization. Based on this definition, the prestige of an organization i increases with the demand of i's network time and energy.
Contacts	Number of other organizations in the community with which the organization has collaborated on the basis of co-authorships or co-inventorships.
	CO-VARIATES MEASURING IN-HOUSE RESEARCH EFFORTS
Cumulative number of researchers	Cumulative number of authors/inventors at the organization for each observation period.
Time	Number of years the organization has been active in the community.

PRODUCT DEVELOPMENT TECHNIQUES AND PROJECT COMPLEXITY IN 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) in the electronics industry. The framework, by means four successful case studies were examined, showing agreements and disagreements in respect to the hypothesised relations, represents a tool for checking the effectiveness of the main product development techniques in different situations.

INTRODUCTION

The growing importance of product development, in terms of timeliness and investments in the area of design and engineering of a new product, induces companies to evaluate the advantages of using (whether in combination or not) different techniques and methodologies [1]. While there is quite a vast amount of literature dealing with the impact of techniques on product development performance [2], 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, among which:

- 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 Clark & Fujimoto's product complexity and project scope [3].

According to the classification worked out by Clark and Fujimoto, the complexity of the product and the range of the project are respectively considered as: *variety* (product range as number of product configurations) 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", 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 theoretic reference 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 sector, of particular interest because product development activities are critical for the achievement of competitive success and require large investments to be made.

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

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 funtion to the production one.

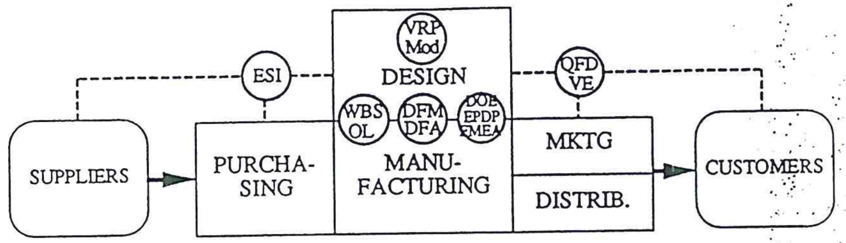

Figure 1 The Product Development Techniques along the Operational Value Chain

Early Supplier Involvement (ESI)

The ESI, independent 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 [4] [5].

Variety Reduction Program (VRP) and Modularization (Mod)

- The VRP is a technique, theorised by Koudate and Suzue [6] 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 [7] [8] [9] 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" [10].

Design for Manufacturability (DFM) and Design for Assembly (DFA)

- The DFM takes into consideration the effects of product structure on manufacturing costs and "producibility" [11]. Benefitting 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 [12] [13].
- Similarly, the DFA [14] 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) [15].

Work Breakdown Structure (WBS) and Overlapping (OL)

• Product development adoptes 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 [16].

• The "tempification" 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" [17].

By several authors the overlapping concept is associated with that of "Simultaneous Engineering" - SE (or "Concurrent Engineering" - CE) [18], but this latter has acquired different and broader meanings in the literature, often going beyond the original one [19].

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 [20], 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 [21]. 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 certain 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" [22]).

• The FMEA is a technique for evaluating the 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.

Quality Function Deployment (QFD) and Value Engineering (VE)

Among the techniques at the interface between design and marketing [23], we here consider the Quality Function Deployment (QFD) and the Value Engineering (VE).

• The QFD is a methodology which originated in Japan at the end of the 60's. 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 [24] 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 [25]. The VE is a method for 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.

RELATIONSHIPS BETWEEN PRODUCT DEVELOPMENT TECHNIQUES AND PROJECT COMPLEXITY

In this paragraph the hypothesised relationships between product development techniques (grouped into six classes) and the project complexity variables (product specification origin, product complexity, project scope) are presented. These hypotheses refer to the intensity of the link between each technique and each variable, considered individually.

Early Supply Involvement (ESI)

• Product specification. In the companies in which the Product Specifications are made By the Customer (from here on PSBC) the sub-contractors 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.

• Variety. Unpredictable. The increase in the production mix seems to augment 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 use (= 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.

• 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.

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

• 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 lessen the time to market.

Variety Reduction Program (VRP) and Modularization (Mod)

• 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 reasons of cost (a higher productive volume) while modularization enables the firm to more effectively withstand the uncertainties of demand.

• 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 easy the management and programming burden while still maintaining the product's high number of final configurations.

• Innovation. 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.

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

• 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.

Design for Manufacturability (DFM) and Design for Assembly (DFA)

• 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 assemblebility of the product. Such efforts cannot be justified in connection with basically lower volumes of production (PSBC), as the productive process is more flexible.

• Variability. 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 assemblebility 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.

• Innovation. 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.

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

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

Work Breakdown Structure (WBS) and Overlapping (OL)

• Product specification. 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.

• 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 rigidly structure the planning activities and search for as much overlapping as possible.

• Innovation. The need for a precise structuring of the activities and the utilisation of overlapping become greater the higher the innovative content incorporated into the product. In fact innovation is generally the result of inter functional and interdisciplinary contributions (= a greater need for co-ordination) and lengthens the time of product development (with a more rigorous need for scheduling and overlapping).

• Commonality and carryover. The less the commonality and carryover the greater is the work load of the product development departments. The need for the timely scheduling of the activities thus grows as commonality and carryover decrease.

• 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.

Design of Experiments (DOE), Early Problem Detector Prototyping (EPDP), Failure Mode Effect Analysis (FMEA)

• 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.

• Variety. Unpredictable. Under the same conditions of entire 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 ideals with 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.

• 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.

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

• 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.

Quality Function Deployment (QFD) and Value Engineering (VE)

• Product specification. The use of QFD appears to be more critical in PSIH firms which do not relate directly with 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.

• Variety. 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 variety that the company proposes to the market.

• 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 sensitiveness to the actual expectations of the customer and a careful evaluation of the costs of the new products.

• Commonality and carryover. The lower the carryover 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.

• Supplier involvement. The use of the techniques in question appears to be advisable independently of the amount of recourse to outside.

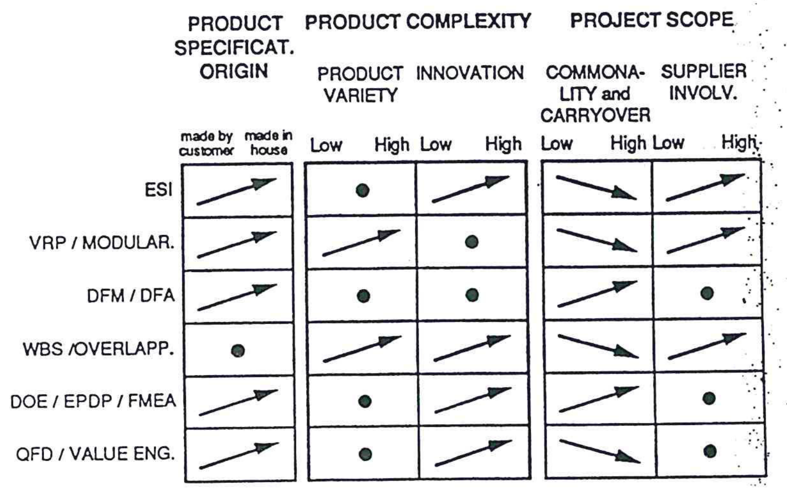

Figure 2. The hypothesised relations between product development techniques and project complexity variables

CASE STUDIES EXAMINATION

In order to verify the hypothesis on relationships between techniques and project complexity variables, outlined above, an in depth empirical survey is needed and a certain number of sample firms, high enough as to permit the exploration of all possible combinations between the environmental variables examined.

Case 1.	• turnover: 66 billiard lire; employees: 228. • main products: -electronic cards; -automotive electronic systems for the supervision of plants for working metals.
	• 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 carryover: low. The technical complexity and the almost complete absence of repetition limits carryover. • supplier involvement: high. The company is strongly decentralised and makes ample use of outside know-how.
Case 2.	• turnover: 59 billiards 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 carryover: 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, oligopolystic market) has up to now prevented the company from having collaborative relations with the suppliers.
Case 3.	• turnover: 49 billiards 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 carryover: low. The variability in demand and the need to offer the market a highly customised product reduces carryover. • supplier involvement: high. The company frequently requires the development and production of specific parts from the outside.
Case 4.	• turnover: 318 billiards 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 carryover: high. Electronic cards and components lends itself to reutilisation 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.

Table 1 The case study firms

Here we have been limited to an initial test of the theoretical framework with the purpose of setting up further the framework. Four electronic companies have been singled out that are characterised by different product specifications, product complexity, project scope. These four companies where investigated to determine the nature and intensity of use of product development techniques adopted. The companies are briefly introduced in the table 1.

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

Early Supplier Involvement (ESI)

The more extensive use of these techniques in contexts in which the commonality and carryover ratio is low and the product specifications are made in house is confirmed by the cases examined. 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.

Variety Reduction Program (VRP) and Modularization (Mod)

The more widespread use of these techniques in contexts in which the commonality and carryover 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 no 3, in which scarce use is made of the techniques even in presence of high productive variety.

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.

Design for Manufacturability (DFM) and Design for Assembly (DFA)

The more extended use of these techniques in contexts where the commonality and carryover 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.

Work Breakdown Structure (WBS) and Overlapping (OL)

The more intense application of WBS and OL techniques in contexts characterised by greater variety, a lower carryover ratio and greater supplier involvement is confirmed by the empirical evidence, as is the lack of a direct link with the product specifications. 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.

Design of Experiments (DOE), Early Problem Detector Prototyping (EPDP), Failure Mode Effect Analysis (FMEA)

The more intense application of these techniques in contexts characterised by greater amounts of innovation and a higher "carryover" ratio proposed in the theoretical model is confirmed by the cases. However there is not a strong link between the use of the techniques and the product specification origin. 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.

Quality Function Deployment (QFD) and Value Engineering (VE)

The cases confirm the trends shown by the theoretical model regarding the degree of innovation, the carryover ratio and the product specifications origin, except for case 4 in relation to the carryover ratio. The lack of a link between the use of these techniques and the variety of the products and supplier involvement respectively, is confirmed.

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.

CONCLUSIONS

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 electronic sector, and showed agreements and disagreements in respect to the hypothesised relations. At this point an extensive survey on an numerically adequate sample could verify in detail the hypothesised relations and the analysis of the combined influence of the different project variables on the single product development techniques.

REFERENCES

[1] Wheelwright S.C., Clark K.B., *Revolutionazing Product Development*, The Free Press, New York, 1992;

[2] Cusumano M.A., Nobeoka K., «Strategy, Structure and Performance in Product Development: Observations from the Auto Industry», *Research Policy*, no.21, pg.265-293, 1992;

[3] Clark K.B., Fujimoto T., *Product Development Performance*, Harvard Business School Press, MA, 1991;

[4] Clark K.B., «Project Scope and Project Performance: The Effect of Parts Strategy and Supplier Involvement on Product Development», *Management Science*, vol.35, no.10, pg.1247-1263, 1989;

[5] Dowlatshahi S., «Purchasing's Role in a Concurrent Engineering Environment», *International Journal of Purchasing and Materials Management*, vol.28, no.1, pg.21-25, 1992;

[6] Koudate A., Suzue T., *Variety Reduction Program: A Production Strategy for Product Diversification*, The Productivity Press, Cambridge, MA, 1990;

[7] Rajput S., Bennett D., «Modular System Design and Control for Flexible Assembly», *International Journal of Operations & Production Management*, vol.9, no.7, pg.17-29, 1989;

[8] De Toni A., Zipponi L., «Operating Levels in Product and Process Design», *International Journal of Operations & Production Management*, vol.11, no.6, pg.38-54, 1991;

[9] De Toni A., Zipponi L., «Product Standardization and Process Similitude», *Integrated Manufacturing Systems*, vol.2, no.1, 1991;

[10] Mather H., *Competitive Manufacturing*, Prentice-Hall, Englewood Cliffs, NJ, 1988

[11] Wheelwright S.C. Clark K.B., *Revolutionazing Product Development*, The Free Press, New York, 1992;

[12] Niebel B.W., Liu C.R., «Designing for Manufacturing», in Salvendy G. (ed.), *Handbook of Industrial Engineering*, 2nd edition, John Wiley & Sons, New York, 1992;

[13] Stoll H.D., «Design for Manufacture», *Manufacturing Engineering*, pg.67-73, january 1988;

[14] Boothroyd G., Dewhurst P., *Product Design for Assembly Handbook*, Boothroyd & Dewhurst, Wakefield, RI, 1987;

[15] Schonberger R.J., *Bulding a Chain of Customers*, The Free Press, New York, 1990;

[16] Koudate A., *Project Management*, JMA, Tokio, 1990;

[17] Clark K.B., Fujimoto T., *Product Development Performance*, Harvard Business School Press, MA, 1991;

[18] Nevins J.L., Whitney D.E. (eds.), *Cuncurrent Design of Products and Processes*, McGraw-Hill, New York, 1989;

[19] Trygg L., «Simultaneous Engineering: A Movement or an Activity of the Few?», pg.569-582, *1th International Product Development Management Conference on New Approaches to Development and Engineering*, Brussels, May 18-19, 1992;

[20] Ettlie J.E., Stoll H.W., *Managing the Design-Manufacturing Process*, McGraw-Hill, New York, 1990;

[21] Wang H.S., Koo T.-Y., Lu I.-Y., «Design of Experiments», in Salvendy G. (ed.), *Handbook of Industrial Engineering*, 2nd edition, John Wiley & Sons, New York, 1992;

[22] Clark K.B., Fujimoto T., *Product Development Performance*, Harvard Business School Press, MA, 1991;

[23] Dowlatshahi S., «A Novel Approach to Product Design and Development in a Concurrent Engineering Environment», *Technovation*, vol.13, no.3, pg.161-176, 1993;

[24] Akao Y., *Quality Function Deployment: Integrating Customer Requirements into Product Design*, The Productivity Press, Cambridge, MA, 1990;

[25] DeMarle D., Shillito M.L., «Value Engineering», in Salvendy G. (ed.), *Handbook of Industrial Engineering*, 2nd edition, John Wiley & Sons, New York, 1992.