The Effects Of Concurrent Product Development On Product Development Performance

Birol Akyüz
Bilecik University
Faculty of Engineering
Bilecik, Türkiye
birol.akyuz@bilecik.edu.tr

A. Yeşim Yayla
Marmara University,
Technical Education Faculty
Istanbul, Türkiye
yayla@marmara.edu.tr

Abstract: The intensive competition in global world markets has shown that existence of enterprises is only possible by ensuring customer satisfaction. Ensuring customer satisfaction is possible by developing products that can meet expectations of customers. The companies which can determine demands and expectations of customers fastest and most correctly, reflect this information on product development process in a short time and introduce these products designed with a customer-focused approach will be the companies that can succeed in today's competitive environment. One of the sectors that successfully take place in Turkey's global competition is Ceramic Sector. This Ceramic Sector is of great importance in world markets with its high quality products with low costs. One of the most important factors affecting product development performances of the companies in the sector is the successful implementation of concurrent product development technique. In this study, the effects of concurrent product development process on product development performance in Turkish ceramic sector were studied by investigating the factors affecting concurrent product development process.

Introduction

Together with increasing demands and expectations of customers that change continuously, shortening of life time of products and demand for lower costs cause a pressure on product development speed of companies (Eppinger and Chitkara, 2006). Enterprises spend more money from their budgets on product development studies and carry out their product development studies in a systematically and planned way (Brown et al., 2004). This has raised the importance of concurrent product development processes in the enterprises (Goetsch and Davis, 2006; Cooper, 2001). Profits and competitiveness of the companies having high product development performances are highly improved (Brown et al., 2004; Swink, 2002).

The main features that make companies superior to their rivals in product development studies are; carrying out studies with product development teams which customers and suppliers take part in, aiming concurrent product development approach in order to pass beyond others by means of especially cost and speed (McGrath, 2004; Ulrich and Eppinger, 2003).

Product Development Approaches

Companies are constantly striving to improve the performance of their new product development activities. Product development approaches are based on two different methods. These are sequential-serial or traditional product development and concurrent product development.

When entering the global market the companies encounter several difficulties, the most important one being excessive time for new product development. This problem can be solved by transition from sequential product development to concurrent product development.

Sequential-Serial Product Development

Sequential product development, also known as sequential-serial engineering or traditional product development, is the term used to describe the method of process and production in a linear format. The different steps are done one after another, with all attention and resources focused on that one task. After it is completed it is left alone and everything is concentrated on the next task (Prasad, 1996).

In sequential product development, the various functions such as design, manufacturing, and customer service are separated. The information in serial product development flows in succession from phase to phase. For example, the prototype model, verified by either simulation or prototyping or both, is reviewed for manufacturing, quality and service. Usually, some changes are suggested after the review. If the suggested changes in the design are made, they are increases in the cost and time to develop the product, resulting in delays in marketing the product launching (Maylor, 1997). If the changes cannot be made because of market pressure to launch the product quickly, or the fact that the design is already behind schedule, then specialists in other functional areas or managers from manufacturing, quality, and service, among others, are informed of the impending problems.

In sequential product development a department starts working only when the preceding one has finished, and, once a department has finished working on a project, or part of a project, this is not planned to come back, information flow is only one way (Ainscough et al., 2003, p.426; Rosenau, 2000).

Sequential product development process was carried out in stages by the various functions in a company. The marketing department would conduct its research and create a new product concept, which it would pass on to the design engineers. They would then design a product with no thought for how it was to manufactured and pass it on to the manufacturing engineers, who would redesign it to be manufacturable. They would then pass the designs on to the purchasing department to buy the necessary components. Because very little communication occurs between functions, even at the handovers, this process has become known as "throwing it over the wall". This lack of communication led to frequent design changes, for example if the design is dependent on a component that has been discontinued by a supplier, a new component or technology has been developed that will improve the product, or the market has changed. Each change requires returning to the early stages of the cycle, extending the time to market and increasing the likelihood of further change. The process was inefficient, expensive and led to badly made, badly designed products that didn't meet customer's needs (Otto and Wood, 2001; Prasad, 1996). A flow diagram of the sequential product development organization is shown in Fig. 1.

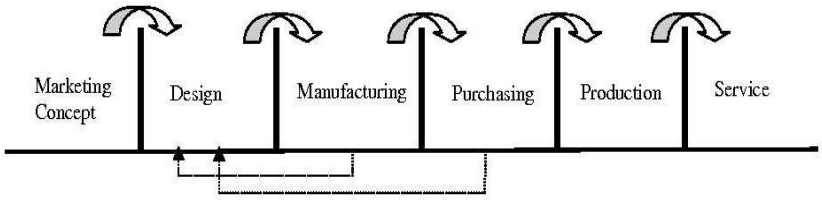

Figure 1: Sequential-serial product development (Hartly, 1998).

Sequential product development is characterized by downstream departments supplying information to design only after a product has already been designed, verified and prototyped (Hartly, 1998), in order to change what design engineering did wrong, or what could have been improved. A flow diagram of the serial design engineering organization is shown in Fig. 2.

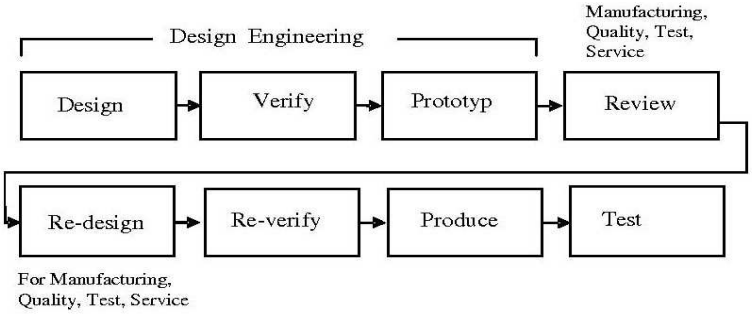

Figure 2: Sequential-serial product development on design process (Staudacher et al., 2003, p.226).

Concurrent Product Development

Concurrent product development approach is a systematic approach enabling possible concurrent development of a product in related processes and its integration with the processes (Koufteros et al., 2001; Ribbens, 2000; Poolton and Barclay, 1998). Concurrent product development applications are based on carrying out the activities in product development processes concurrently and on working of all the related processes in a concurrent, seen Fig.3., and integrated manner including different departments of the enterprise, design, production and support services (Griffin, 2002; Maylor, 1997). Especially, collaboration of design and production departments is important for developing products consistent with customer needs, reducing the costs, enhancing the quality and increasing the speed (Barclay et al, 2000; Swink, 1998; Salomone, 1995),

Main features of concurrent product development practices are; being sure that process design is parallel and concurrent, realizing all the activities in a coordinated way, teams' making decisions about product development and processes, using cross functional teams, gathering of the team members regularly, information sharing and collaboration between the teams, shortening product development and market entry times, reducing the costs and developing products consistent with customer needs (Minderhoud and Fraser, 2005; Kusar at al., 2004). Concurrent product development processes affect product development performance in a positive way (Cooper et al., 2003; Griffin, 2002).

Concurrent product development is known as concurrent engineering, modern Product Development, overlapping Product Development, integrated Product Development and cross functional Product Development. Concurrent product development, sometimes called simultaneous engineering, or parallel engineering has been defined in several ways by different authors. One of the most popular one is that by Prasad (1996), who state that concurrent engineering 'is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support.' This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements (Carter and Baker, 1992).

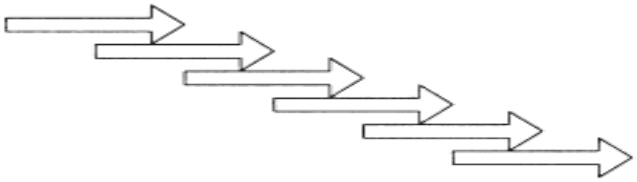

Figure 3: Concurrent product development (Hartly, 1998)

In concurrent product development all functional areas are integrated within the design process. In this case information continuously flows back and forth among all functions. During the design process concurrent product development draws on various disciplines to trade-off parameters such as manufacturability, testability and serviceability, along with customer performance, size, weight, and cost (Ainscough et al., 2003). A flow diagram of concurrent product development is shown in Fig. 4.

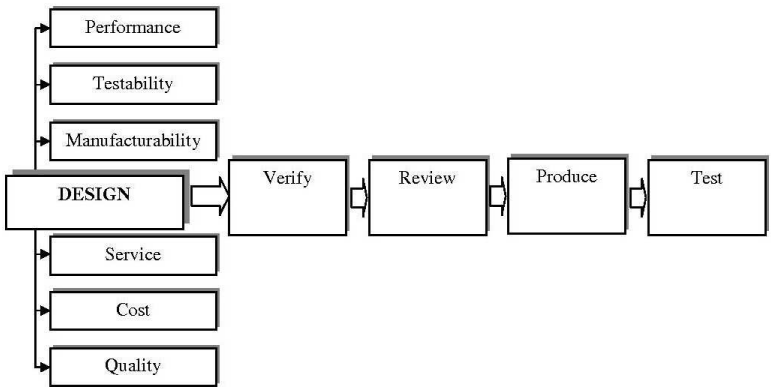

Figure 4. Concurrent product development on design process (Staudacher et al., 2003, p.226).

The decision making process in a concurrent product development environment differs from sequential engineering in that at every stage decisions are taken considering the constraints and the objectives of all stages of the product life cycle, thus taking at the product design level issues that are usually addressed much later, thus giving the possibility to achieve a better overall solution (Prasad, 1996). The integration of other functional areas within the design process helps to discover hard to solve problems at the design stage. Thus, when the final

design is verified, it is already manufacturable, testable, serviceable, and of high quality. The most distinguishing feature of concurrent product development is the multidisciplinary, cross-functional team approach. Product development costs range between 5% and 15% of total costs, but decisions taken at this stage affect 60–95% of total costs (Kusar et al., 2004). Therefore it is at the product development stage that the most relevant savings can be achieved. Examples of successful concurrent product development implementations are reported from all over the world (Kusar et al., 2004; Ainscough et al., 2003; Zirger and Hartly, 1996).

In concurrent product development, different tasks are tackled at the same time, and not necessarily in the usual order. This means that info found out later in the process can be added to earlier parts, improving them, and also saving a lot of time. This is a method by which several teams within an organization work simultaneously to develop new products and services and allows a more stream lined approach. The concurrent product development is a non-linear product or project design approach during which all phases of manufacturing operate at the same time - simultaneously. Both product and process design run in parallel and occur in the same time frame. Product and process are closely coordinated to achieve optimal matching of requirements for effective cost, quality, and delivery. Decision making involves full team participation and involvement. The team often consists of product design engineers, manufacturing engineers, marketing personnel, purchasing, finance, and suppliers (Ainscough et al., 2003; Swink, 1998).

Concurrent Product Development vs Sequential Product Development

Concurrent product development is a simultaneous development of product and process. It is used to achieve "better, faster and cheaper" new product introduction as it aims to improve the quality of new products as well as bringing them to the market more quickly and cheaply than the serial-sequential product development approach.

When developing a new product (here we are dealing with development of a product and its production process), it is necessary to harmony all development stages. The product development time can be reduced by concurrent product development time and it is reduced by 50% or more due to the following reasons (Prasad, 1996):

* Activities run in parallel,
* Team members have regular meetings which allow fast and efficient exchange of information,
* Responsibility for all product features is transferred to teams (no time is wasted for searching the person ''who is to be blamed for errors '').

In the serial-sequential product development the design "was thrown over the wall". On the other hand, in the concurrent product development the departmental barriers are removed. In other words, the designers or cross functional team members have to get involved and discuss the all issues related to manufacturing at the early stage of the design process (Kusar et al.,2004; Ainscough et al., 2003).

Concurrent product development represents an organisation's ability to carry out product development as a series of overlapping phases, which delivers product on time, to provide customer satisfaction at the right price (Prasad, 1996). Therefore concurrent engineering can be defined as:

- A philosophy of product development: Integrating multiple design issues,
- A method of product design: Integration of multidisciplinary folks into design team,
- A method to lead people: Design issues are represented by all the relevant in the people,

The goal of Concurrent Engineering is to improve the interactive work of different disciplines affecting a product. The following are some of the benefits (Crowson, 2006; Ribben, 2000):

- Well-understood user requirements,
- Reduce cycle times,
- First time quality producible designs,
- Shorter development spans, Eliminate the redesign procedure,
- A smoother transition to production
- A new respect for other teammates,
- Lower cost, decrease production cost results from the minimization of the product life cycle,
- Teamwork - Human Resources are working together for a common product,
- Highly satisfied customers, the company can increase the prospect of delivering a quality product to the customer.

Concurrent product development pays off in (Crowson, 2006; Ainscough at al., 2003; Prasad, 1996):

- Product development cycle time reduced 40-60%,

- Manufacturing costs reduced 30-40 %,
- Engineering change orders reduced more than 50 %,
- Scrap and rework reduced by as much as 75%.

Concurrent product development is a commonsense approach to product design, development, production and support. By collecting and understanding all requirements that the product must satisfy through its life cycle at the start of concept definition, we can reduce cost, avoid costly redesign and rework, and shorten the development process. We do this by capturing all customer requirements and expectations and involving all related disciplines from the start. Working as a team on all product related processes, we can provide for a smooth transition from development to production (Crowson, 2006).

Primary elements of concurrent product development are voice of the customer, multidisciplinary teams, automation tools and techniques and process management (Backhouse and Brookes, 2004).

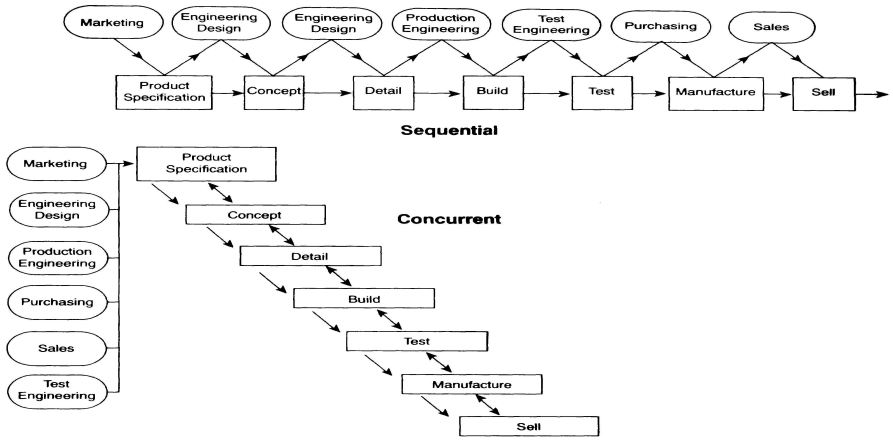

Figure 5: Sequential and concurrent developments of new products (Backhouse and Brookes, 2004)

Cost of concurrent product and process development (CE) are lower than sequential product and process development costs (SE) costs, as presented in Fig.6.

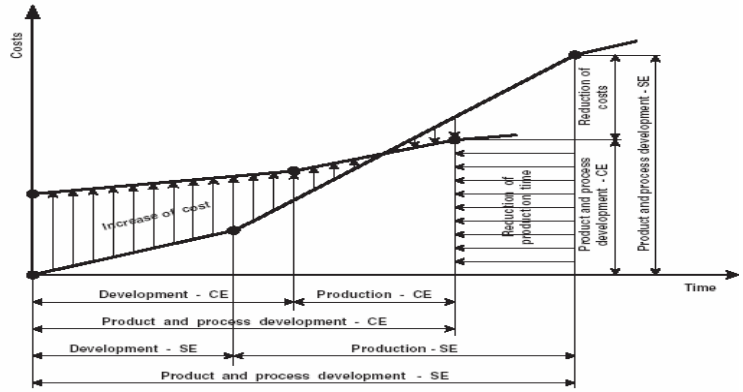

Figure 6: Sequential and concurrent developments of new products (Kusar et al., 2004).

Product Development Performance

Only recently has there been a widespread understanding of the need to measure the different facts of success using product development performance metrics. A number of studies have attempted to define and categories them. A number of metrics exist at the firm level to establish the overall success rate of development programmes. They are as follows (Crowson, 2006; Kusar et al.,2004; Ulrich and Eppinger, 2003; Barclay et al., 2000; Prasad, 1996; Clark and Fujimoto, 1991):

- Sale success of the products developed in the market,
- Satisfaction of the customers of our enterprise,

- Average product development costs,
- Competition power of our enterprise,
- Product range (scale) of our enterprise,
- Number of products developed,
- Product development speed,
- Amount saved (%) in the budget for R&D studies.

One of the factors that affects product development studies is concurrent product development processes (Brown et al., 2004; Ulrich and Eppinger, 2003; Prasad, 1996; Shina, 1994), see Fig.7. Determining the factors that affect concurrent product development processes will enhance the success of product development processes of the companies, leads us to hypothesis that:

Hypothesis: There is relation between product development performance and concurrent product development approach.

Methodology

The data in this study have been obtained by applying a survey prepared according to the 5-point likert scale to the companies in Turkish ceramic sector. The persons were interviewed face to face and the questions were answered by directors in charge of product development, product development team leaders or team members. The data obtained from the questionnaire were studied by making factor analysis, reliability analysis, correlation analysis and regression analysis.

Theoretical model of the research (see Fig. 7) consists of concurrent product development and product development performance. Product development Performance (PDP) is dependent variables of the study.

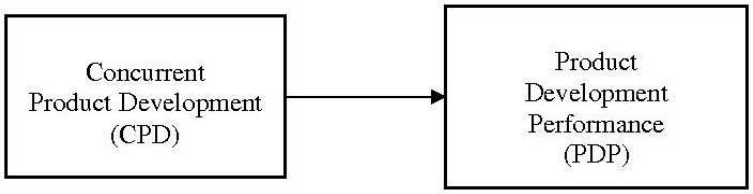

Figure 7: Theoretical model of the research.

Scope of the Research and Preparation of the Questionnaire

The research covers the companies in Turkish Ceramic sector. It consists of 60 companies, 52 of which responded positively to our demand for the survey and answered the survey.

In preparing the questionnaire, we used the conceptual information which exists in the references obtained in literature scanning carried out in the studies while forming the theoretical model of the research. The survey sheet consists of questions that evaluate the variables in the theoretical model of the research. All the questions in the survey were prepared in such ways that only one answer was valid so that the persons answering these questions could give define answers. The persons answering the questions were asked not to leave any question empty.

Scales Used in the Questionnaire

Scales used in the survey were arranged consistent with theoretical model of the research. Concurrent product development was evaluated with a scale of six questions and product development performance with a scale of eight questions. In answering the scales of concurrent product development on the survey sheet, the 5-point likert scale was used as; (1) totally disagree, (2) don't agree, (3) no idea (4) agree, (5) totally agree. Those who answered the survey for product development performance were asked to evaluate product development performance of enterprises in last three years according to the sector average. The 5-point likert scale was used for evaluation as; (1) much lower than the sector average, (2) lower than the sector average, (3) same as the sector average, (4) higher than the sector average, (5) much higher than the sector average.

Data Collection

As data collection method, companies were visited and company authorities were asked to answer the survey by face to face interview method. By face to face interview method, the questions were understood correctly and answered easily as their demands for additional explanations about the questions were met instantly.

Data Analysis and Findings

In data analysis, SPSS 11.5 statistics programme was used. Methods used in data analysis are factor analysis, reliability analysis, correlation analysis and regression analysis. Hypothesis was evaluated according to the results obtained from regression analysis.

Of 60 companies in Turkish ceramic sector, 52 of them answered the survey. Twenty eight of these companies (53.8%) work in ceramic tile industry, 16 of them (30.8%) in health products industry (sanitaryware), 4 of them (7.7%) in tableware and ornament 4 of them (7.7%) in technical ceramic field. Of the persons who answer the survey, 44.2% were R&D manager, 17.3% technology manager, 13.5% factory manager, 9.6% production manager, 5.8% R&D engineer and 5.8% quality assurance manager.

Analyses and Results

Reliability analysis was carried out in order to determine the reliability of the survey questions. Reliability coefficient (Cronbach's coefficient) is $\alpha = 0.7439$. According to the results of the analysis, the fact that reliability coefficient (α) has a value higher than 0.5 shows that the survey questions were reliable and valid (Özdamar, 2002; Manly, 1994).

Factor loadings were studied by applying factor analysis to the variables in the research model (see Appendix A). According to Appendix A, total variance explained by variables related with concurrent product development characteristics is 62.206 %.

Correlation analysis was applied to the variables in the scope of the research and extent and direction of the relation between the variables were investigated (Manly, 1994). Pearson's correlation coefficients related with the variables, average and standard deviation values are seen in Tab. 1.

		Mean	Std. Deviation	PDP	CPD
PDP	Pearson Correlation	3.6226	0.46672	1	0.246
	Sig. (2-tailed)			.	0.079*
CPD	Pearson Correlation	3.6859	0.62418	0.246	1
	Sig. (2-tailed)			0.079*	.

P<0.1*, P<0.05**, P<0.01***

Table 1: Correlations, Mean, Standard Deviation.

As seen in Tab. 2, values for regression model of concurrent product development are; $p<0.1$, $F= 3.208$ and $R^2 = 0.060$. This shows that variable included in the model defines 6.0 % of variance of product development performance. Concurrent product development affects product development performance at $p<0.1$ significance level and with beta value 0.246. According to Tab. 2, it is seen that there is a positive. This result supports the hypothesis H_1. The regression equation is given below.

$$y = \beta_0 + \beta_1 x + \varepsilon$$

Independent Variable	Standardized Coefficients Beta β	P	Constant β_0	R^2	F	P
Concurrent Product Development				0.060	3.208*	0.079
Constant		(0.000)	(2.946)			

Concurrent Product Development	0.246*	0.079				

P<0.1*, P<0.05**, P<0.01***

Table 2: Product development performance regression.

Conclusions

Continuous and rapid changes in global markets have raised the importance of product development activities of the companies. In today's competitive world in product development studies and concurrent product development processes, it is known that it is important for the enterprises to work by collecting different individuals from different principles, especially by means of product development speed, cost and product development performance. Concurrent product development process is known to be effective on product development performance. Determining the factors that affect concurrent product development processes will enhance the success of product development studies of the companies. The companies which succeed in product development will pass beyond their rivals and launch their products and services earlier than them.

The results obtained from the study briefly are: concurrent product development process has a positive effect on product development performance. Product development is related with all functions of the enterprise and it should be seen as a whole. It is not only one department's or a few persons' responsibility, but a team work which requires involvement of all employees voluntarily. The fact that teams consist of people who work in different departments of the enterprise affects the speed of product development processes. Reflecting the demands and expectations of the customers and suppliers on product development processes and their existence in product development processes is important for achieving the quality dimensions of the product. It is also important for enhancing communication, making information sharing easier and coordinating product development activities. Hence, this enables the companies to catch possible opportunities in the sector in which they show activity and get a serious advantage in the competition.

For success of the companies in product development; carrying out a significant R&D study and providing all sorts of sources for this, determining stronger sides of the company compared to its rivals and taking good advantage of it, determining weak sides of existing products or processes and seeking ways to solve these, having good knowledge of characteristics and strategies of the rivals in the sector, having good knowledge of characteristics of the customers, determining target customers successfully, determining the number of new products aimed in one year correctly and using product development tools and techniques effectively are quite important in the success of product development studies. It will be extremely beneficial for the companies in the ceramic sector by means of product development performances to evaluate product development studies and plan their product development activities by taking the results of this research into account.

Comp.	Variables	Factor Loading	Total Variance Explained (%)
	CONCURRENT PRODUCT DEVELOPMENT		62.206 %
CPD 1	In our enterprise there are electronic data storage systems through which the employees can easily get access to information about product development	0.748	
CPD 2	In our enterprise product development is a concurrent (parallel) process	0.679	
CPD 3	All sorts of matters and possible problems about product development are discussed in designation stage of product development process	0.829	
CPD 4	In our enterprise designs are made which partially/totally eliminate design changes that may emerge in any stage of product development process	0.846	
CPD 5	In our enterprise great effort and sources are spent in the first stages of product development process	0.688	
CPD 6	Product development teams (cross functional teams) which consist of different persons in product development studies and which suppliers and customers also take part in are used	0.741	
	PRODUCT DEVELOPMENT PERFORMANCE		68.558 %
PDP 1	Sale success of the products developed in the market	0.792	
PDP 2	Satisfaction of the customers of our enterprise	0.835	
PDP 3	Average product development costs	0.828	

PDP 4	Competition power of our enterprise	0.559	
PDP 5	Product range (scale) of our enterprise	0.847	
PDP 6	Number of products developed	0.884	
PDP 7	Product development speed	0.605	
PDP 8	Amount saved (%) in the budget for R&D studies	0.599	

PDP: Product Development Performance CPD: Concurrent Product Development

Appendix A: Factor Loading

References

Ainscough, M.; Neaily, K.; Tennant, C. (2003). *A Self-Assessment Tool for Implementing Concurrent Engineering through Change Management, Int.Journal of Project Management*, 21, (pp.426-430).

Backhouse J.C and Brookes J.N. (2004). *Concurrent Engineering*, John Wiley & Sons, Inc. New York.

Barclay, I; Dann, Z., Holroyd, P.(2000). *New Product Development, CRC Press*, New York, USA.

Brown, M.; Leavitt, P.; Wright, S. (2004). *New Product Development, American Productivity & Quality Center – APQC*, Houston, USA.

Carter, E.D. and Baker, S.B. (1992). *Concurrent Engineering the Product Development Environment for the 1990s*, Addison Wesley Publishing Company Inc., USA.

Clark, K. B. & Fujimoto, T. (1991). *Product Development Performance*, Harvard Business School press, USA.

Cooper, G.R.; Edgett, J.S.; Kleinschmidt, E.J. (2003). *Improving New Product Development Performance and Practices, American Productivity & Quality Center –APQC*, USA.

Cooper, R.G. (2001). *Winning at New Product, 3rd Edition, Published by Basic Books*, New York, USA

Crowson, R. (2006). *Product Design and Factory Development*, Second Edition, Taylor&Francis, USA.

Eppinger, S.D. and Chitkara, A.R. (2006). *The New Practice of Global Product Development*, MIT Sloan Management Review, Vol.47, No.4, (pp.22-30).

Goetsch, L. D.; Davis, B.S.(2006). *Quality Management, Fifth Edition*, Pearson Prentice Hall, USA.

Griffin, A. (2002). *Product Development Cycle Time For Business To Business Products*, Industrial Marketing Management, 31, (pp.291-304).

Hartly, J.R. (1998). *Concurrent Engineering*, Productivity Press, New York, USA.

Koufteros, X.; Vonderembse, M. and Doll, W. (2001). *Concurrent Engineering and its Consequences*, Journal of Operations Management,19, (pp.97-115).

Kusar, J.; Duhovnik, J.; Grum, J. and Starbek, M. (2004). *How to Reduce New Product Development Time*, Robotics and Computer Manufacturing, 20, (pp.2-6).

Manly, B.F.J. (1994). *Multivariate Statistical Methods*, Second Edition, Chapman-Hall, London, UK.

Maylor, H.(1997). *Concurrent New Product Development: An Empirical Assessment, International Journal of Operations & Production Management*, Vol.17, No.12, (pp.1196-1214).

Maylor, H.; Gosling, R.(1998). *The Reality Of Concurrent New Product Development, Integrated Manufacturing Systems*, Vol.9, No:2,(pp.69-76).

McGrath, M.E. (2004). *Next Generation Product Development*, McGraw-Hill Companies, Inc., USA.
Minderhoud, S. and Fraser, P. (2005). *Shifting paradigms of Product development in fast and dynamics markets*, Reliability Engineering and System Safety, 88, (pp.127-135).

Otto, N. K. and Wood, L.K. (2001). *Product Design*, Prentice Hall Inc., USA.

Özdamar, K.: "Paket Programlamalar ile İstatistiksel Veri Analizi", *4.Baskı, Kaan Kitabevi*, Eskişehir, (2002).

Poolton, J.; Barclay, I. (1998). *New Product Development from Past Research to Future Applications*, *Industrial Marketing Management*, 27, (pp.197-214).

Prasad, B. (1996). *Concurrent Engineering Fundamentals*, Volume I, Prentice-Hall, Inc., New Jersey, USA.

Ribbens, A.J. (2000). *Simultaneous Engineering for New Product Development*, John Wiley & Sons, Inc., USA.

Rosenau, D.M. (2000). *Successful Product Development*, John Wiley&Sons, Inc., New York, USA.

Salomone, A.T. (1995). *Concurrent Engineering*, Marcel Dekker, Inc., New York, USA.

Shina, S. G. (1994). *Successful Implementation of Concurrent Engineering Products and Process*, Van Nostrand Reinhold, New York, USA.

Staudacher, A.P; Landeghem, H.V.; Mappelli, M.;Redaelli, C.E. (2003). *Implementation of Concurrent Engineering: A Survey in Italy and Belgium*, *Robotics And Computer Integrated Manufacturing*, V.19, (pp. 226-235).

Swink M. (2002). *Product development-Faster, on-time*, Research and Technology Management, Jul/Aug V.45, N:4, (pp.50-59).

Swink, L. M. (1998). *A Tutorial on Implementing Concurrent Engineering in New Product Development Programs*, Journal of Operations Management, 16, (pp.103-116).

Ulrich, K.T. and Eppinger, S.D. (2003). *Product Design and Development*, Third Edition, McGraw Hill Companies, Inc., New York, USA.

Zirger, J.B. and Hartly, L.J. (1996). *The Effect of Acceleration Techniques on Product Development Time*, IEEE Transactions on Engineering Management, Vol.43, No.2, (pp.143-152).