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Research Paper

CONCURRENT ENGINEERING-AN EMERGING TOOL FOR PRODUCTION INDUSTRIES IN PRODUCT DESIGN & DEVELOPMENT

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Traditionally, key quality refers to conformance to design specifications. Components not meeting the specifications are identified 'rejects'. This emphasis on building quality by identifying poor quality components and throwing them aside as 'rejects' has a significant cost for the company. Firstly, workers are not being trained on how to produce required high quality and better product design. Secondly, rejected items mean 'scarp' and loss to the company and these many numbers of components have to be manufactured again. Thus, net result is higher cost and larger time consumption. There results in achieving good quality at higher cost & time. The tough international competition has made industry realize that for success, the winner has to learn how to produce better products design & development and quality at less cost and less time. Based on the literature review, this study has brought out key quality-strategies and practices followed by international companies which include customers' requirement analysis, use of multi-functional quality-management teams reliability engineering techniques such as Simultaneous Engineering / Concurrent Engineering Approach, and quality-cost management techniques, Design for cost and time to market etc.

Keywords: Quality, Product Design & Development, Simultaneous engineering

INTRODUCTION

Product for Industry

Customer & Competitor Focus

In the Industry environment, product design (and its development) is basically aimed at making certain profit by selling the product to the customers in the market, who use the product to meet their requirements and are willing to pay for it. But before buying any product, a customer compares the particular product with other similar products offered by other competitors. Therefore, Industry Firms have to carry out product-design on the basis of detailed understanding & analysis of the Customers and the Competitors (Xiaopeng *et al.*, 2012). In fact, customers' requirements & preferences undergo change when new products are offered by the Competitors (Andrews, 2005; and Gulati, 2007).

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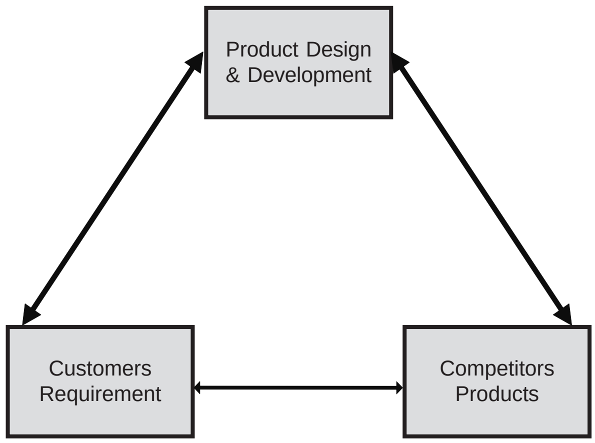
Figure 1: Coupling Between Product, Customers, and the Competitors



Business Risk in Product Development

Due to fast changes in Customers' requirements consequent to increasing competition, product development poses very high risk for the business firm.

Being "Better, Cheaper & Faster" leads to Market Success

As business is becoming more and more globalised, completion is rising very fast, and newer products are being introduced at faster pace than before. Business Firms are striving hard to introduce new-product ahead of their competitors. Therefore, time to reach the market (also called time-to-market) is becoming crucial for product development success. Further, advancements in technology is also facilitating entry of newer and better products in the markets. The customers are now having more choices in the market. Better quality products are now being introduced in the markets at faster pace (lesser time) and at lesser price. Thus, *Better, Cheaper, and Faster* is the new mantra for market-success (Rosenthal, 1998).

STUDY OF PUBLISHED LITERATURE

Approach For Product Design & Development

Project-Approach for Product Development

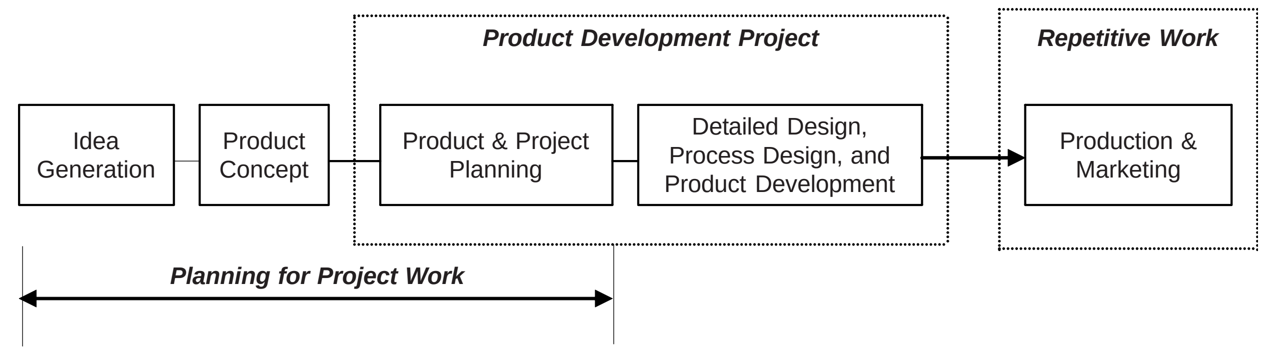
New product development is recognized by all industrial sectors as essential to business success. Due to requirements of large resources and the associated business risks, most companies are adopting project-approach for product development. The term 'project' has two major attributes, namely (i) there is a definite 'start' and also a pre-determined, well-defined 'finish' for the project, and (ii) the project is a one-time activity, and is not a repetitive activity. Product development also has these two attributes, and is therefore undertaken as a project.

Product development starts from generation of product ideas and conceptual design. After a particular concept is selected, detailed product design is commenced, paying attention sub-systems, assemblies, sub-assemblies, and the components needed (Xiaopeng *et al*., 2012).

Integrated Consideration of Product Design and its Related Processes

A systematic consideration of product-design along with the processes through which the product will be developed, manufactured and marketed. Further, the new paradigm of being *faster-cheaper-better* requires that the product design must be evolved and finalized in a manner that the product-design caters for the following requirements (Hull *et al*., 1996; Pillai *et al*., 1997; Tennant and Roberts, 2001; Cholrit *et al*., 2011; and Desai & Mital, 2011).

Figure 2: Activities Involved in New-Product Development Project



- Design-for-Quality
- Design-for-Cost
- Design-for-Time (Time-to-Market)
- Design-for-Manufacture
- Design-for-Assembly
- Design-for-Maintenance
- Design-for-Upgradability/Design-for-Flexibility

The importance of "integrated/simultaneous consideration of product design and development issues" lies in the fact that effectively performing the simultaneous consideration can contribute directly to the ultimate market success of the product design & development (Murphy and Kumar, 1997; Smith and Reinertsen, 1998; Cooper *et al*., 2004; Cooper, 2007).

Simultaneous Engineering/ Concurrent Engineering Approach

Japanese Industry has been using this approach, since 1950's, for product-development projects with specific objective of reducing overall development time and also achieving higher product quality at a lesser cost. This approach was studied and adopted by number of American & European Teams during early 1980s. It was adopted by their Industry Firms in 1983 onwards, with mixed success initially, but the process was considerably improved during 1984-1995 period. Considerable academic research was carried out in American and European Universities to support the Industry Firms in mastering the *Cheaper-Better-Faster* paradigm in product development projects (Ford, 1988; Cooper, 1994; Murphy and Kumar, 1997; Berggren and Nacher, 2001; Sharma, 2011).

In its strict sense, this approach requires simultaneous execution of two (or more) upstream and downstream stages like 'product design' and 'design of related subsequent processes'; namely for manufacture, assembly, test & evaluation, and marketing. The subsequent stages are dependent on generation and finalization of product information by the upstream stage (based on which issues for subsequent stages are decided and finalized).

BASIC PROCESS FOR SIMULTANEOUS CONCURRENT/ OVER LAPPING DEVELOPMENT PHASES

Figure 3: Sequential and Overlapping Development Phases for Product Development

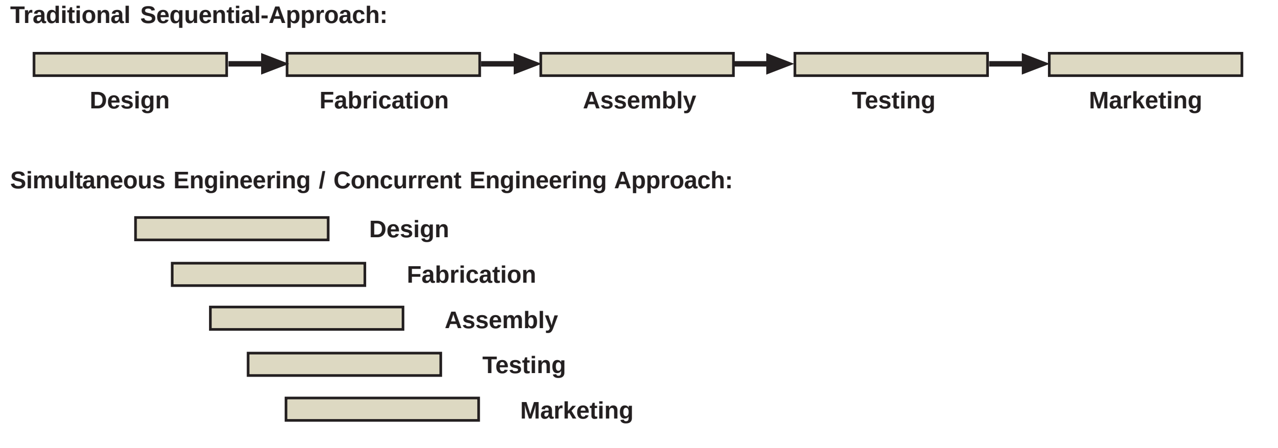
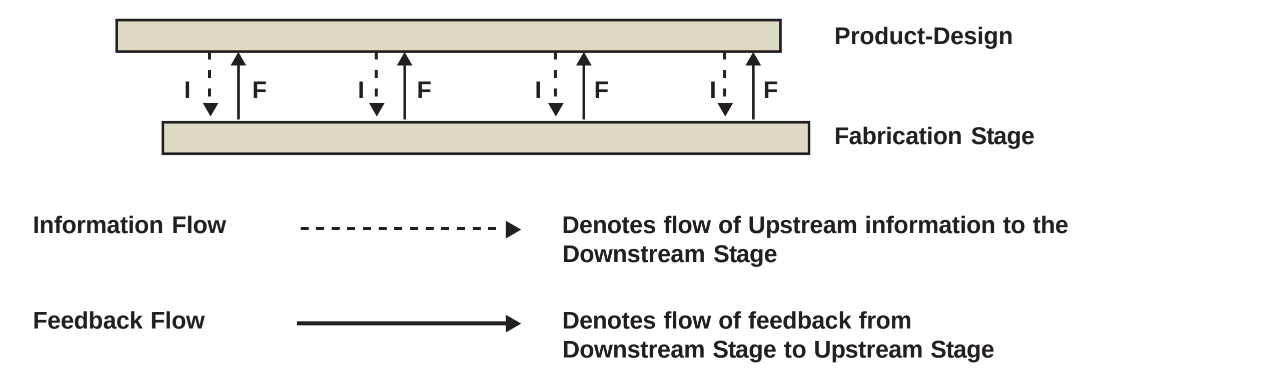


Figure 4: Information Sharing & Feedback Flow among Overlapped Development Phases



As an example, a two-stage development process is considered, being progressed through simultaneous/concurrent/overlapping phase approach. First, work starts of the upstream stage of product design. As soon as some meaningful design information is generated, the same is shared (made available) to the down-stream stage. The expert of the downstream stage consider and analyze the information received, to check if it is meeting requirement of downstream stage. The above iteration of flow of design-information followed by flow of feedback information takes place number of time, again and again, till both upstream and downstream information get evolved in linked manner; thus completing work on both phases.

ISSUES IN MANAGING SIMULTANEOUS/CONCURRENT OVERLAPPING PRODUCT-DEVELOPMENT PHASES

Intense Information Exchange: Product-Information & the Feedback

Basic fundamental issue in ensuring that product design information is made available to all other members of product development team, as soon as such information is generated. The timely sharing of complete information can not be left to the personal efforts of an individual; rather a formal information-flow system needs to be put in place so that complete information is made available to all concerned in timely manner and the corresponding feedback also reaches the design-team in timely manner (Clark and Fuzimoto, 1991; and Sung & Wu, 2011).

In post-2000 era, large computer based "*Information Sharing Systems*" have been evolved. Receipt of product-information and subsequent feedback is managed by appropriate hardware and software system. However, in large and complex projects namely development of Car or Aircraft, human element is also crucial in development and implementation of appropriate "Information Coordination Structure". Thus, proper attention needs to be given to each of the three crucial parts of Project-Information System comprising of (a) *hardware*, (b) *software*, and (c) *humanware* (Schilling and Hill, 1998; Sung and Wu, 2011).

Effectiveness of Overlapping Development Phases for Project Success

Overlapping approach has accelerating impact on the project cycle-time. However optimal overlap depends on the uncertainty-resolution capability of the particular project. Project effectiveness (success) is determined by overlapped stages getting completed properly in a manner that there is saving of time and simultaneously 'quality to the customers' is also improved (Zirger and Hartley, 1996; Cholrit, 2011; Sharma, 2011).

Research by Krishnan (1996) and by Loch & Terwisch (1998) has shown that two factors which help in anticipating effectiveness of overlapped stages are: (a) rate/speed of evolution of upstream information, and (b) sensitiveness of downstream stage in following-up the receipt of upstream stage information. Two set of conditions can be used to understand this effectiveness (effecting overall project success); these are (i) 'slow' and 'fast' evolution of upstream information, and (ii) 'low' and 'high' sensitiveness of downstream stage to the time of receipt & completeness of the upstream stage. This is illustrated in Figure 5 (a) and Figure 5 (b).

Figure 5: (a): Evolution of Product Design Information in Upstream Stage

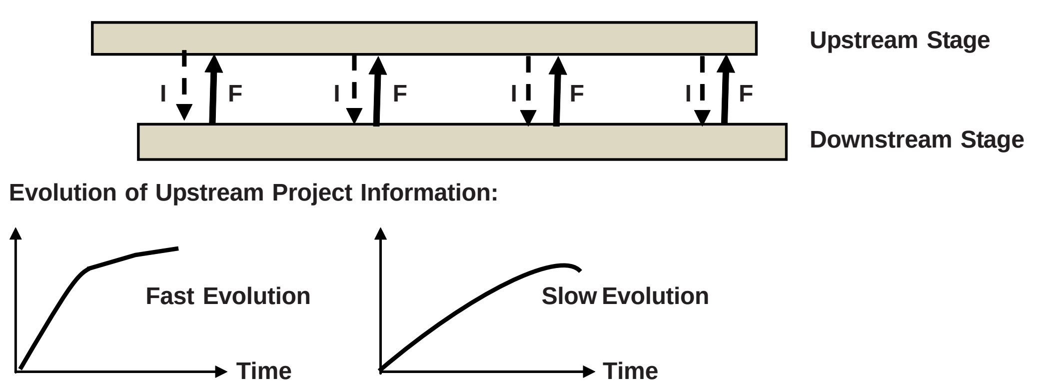
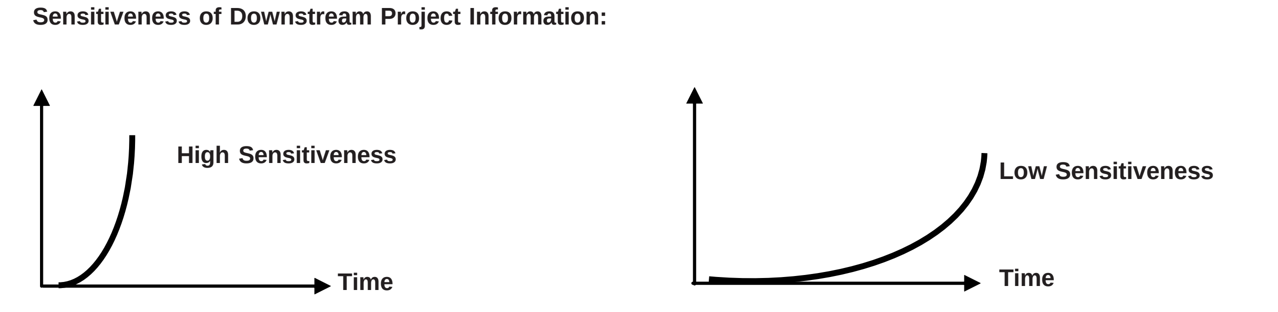


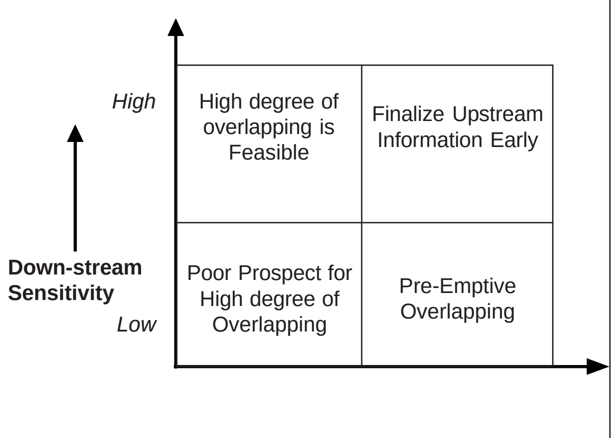
Figure 5: (b): Sensitiveness of Downstream Stage to Changes in Upstream Information



Overlapping activity is generally easier when the upstream evolution is fast, rather when it is slow. Time gains resulting from overlapping activities are larger if uncertainties can be reduced early in the development process (Eisenhandt and Tabrizi, 1995).

The effect of various levels of "evolution of upstream phase" and "down-stream sensitivity" on the feasibility of high-degree of overlapping development phases (concurrent engineering approach) is presented in the figure given below:

Figure 6: Feasibility of High-Degree of Overlapping among Development Phases Concurrent Engineering Approach, (Krishnan *et al.*, 1997



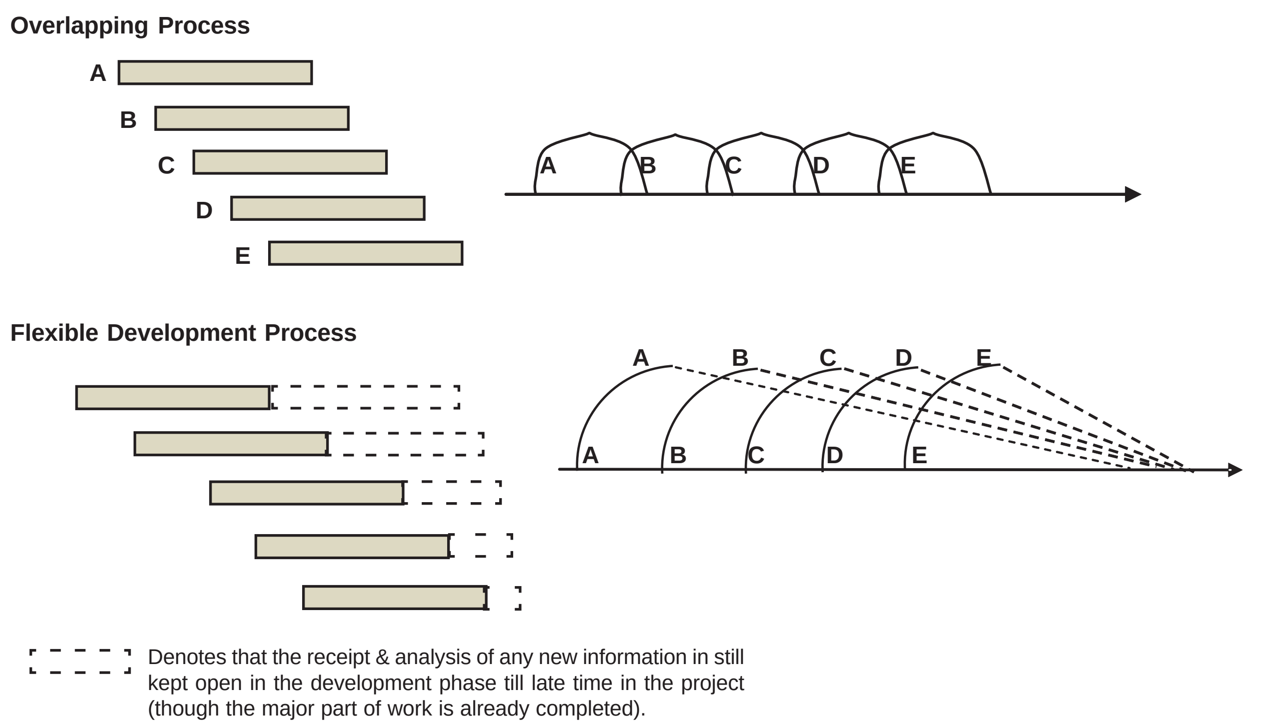
Loch and Terwiech (1998) and Yang (2007) have reported that gains from overlapping activities must be weighed against the delay due to the rework resulting from proceeding in parallel based on preliminary information from upstream stage, which gets revised/changed at a later time.

Empirical research by Joglekar etal (2001) and Watanbe (2007) has shown that "concurrent engineering" (high-degree of overlapping) need not be the optimal work strategy in many settings.

Flexibility in Product Development Process

Therefore, adequate degree of flexibility has to be built into the product-development process so that such changes can be incorporated without excessive penalty of time and cost. Higher is the flexibility, lesser is the penalty for product-design changes at late stage in the project (Sushil 1997 & 2000). Flexible development process allows the product designers to continue to refine/ update the design and to shape products accordingly even after product fabrication or manufacture has begun (Pillai, 1997; Thomke, 2001).

Figure 7: Upstream & Downstream Information Finalization in Flexible Development Process



In flexible development process, though the majority of work in a particular development phase is completed but option is kept open to receive & analyze any "new" information (for higher customer satisfaction / market focus) and to incorporate the required change(s) even upto late stage in the process. All efforts are made to ensure that overall time & cost gets increased only by a minimal acceptable amount. (Takeuchi and Nonanka, 1986; Lansiti, 1995; Hsu Yen, 2013).

Cross-Functional Development Teams

Use of cross-functional teams is a complementary strategy to the use of overlapping development phases (Clark and Fuzimoto, 1991; Zirger and Hartley, 1996; Flint, 2002; Danilovic and Browning, 2007). Such teams are the main drivers of the product development process and facilitate integrated consideration of downstream issues at the upstream stage, which is the primary principal of managing product development using overlapping development phases (Lynn and Akgun, 2000; Prencipe and Tell, 2001; Ulwick, 2002).

Cross-functional teams bring certain key project capabilities: high degree of market focus, flexible sub-processes, periodic project reviews, intra-project co-ordination, and high level of calculated risk-taking (Ulwick, 2002; Paltier, 2005; Sung and Wu, 2011).

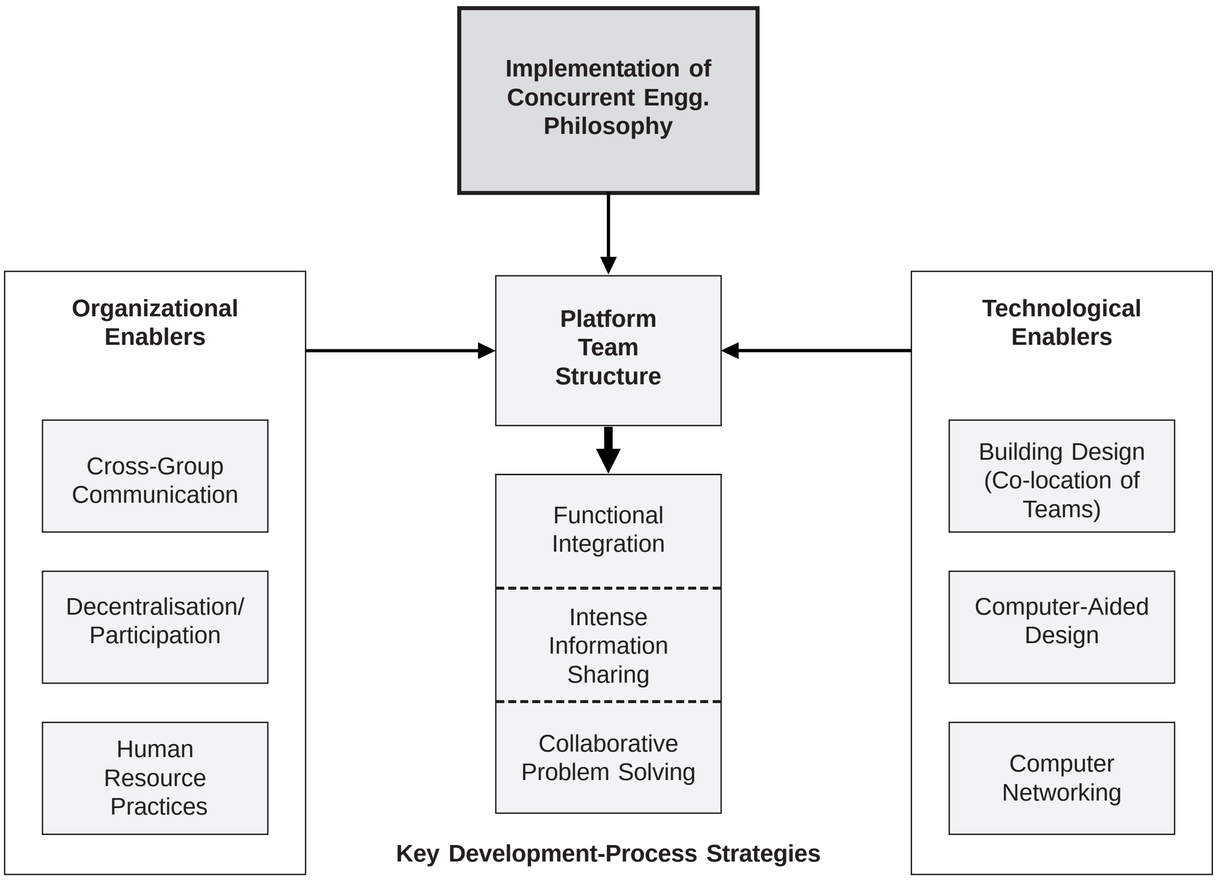
Organizational Structures for Effective Information Sharing & Trade-off Decision

Effective projects are characterized by suitable structures that minimize "changes in product-design", once the execution phase has begun (Cooper, 2004 & 2007). Sequencing of development activities has major impact of need for information which may evolve only in a subsequent activity. Re-sequencing the activity sequence, as done in DSM Matrix, is a common practice for evolving efficient development process (Tennant and Roberts, 2001; Petri *et al.*, 2010).

Information co-ordination is an essential requirements and has to be designed and implemented keeping in view the requirements of overlapping phases and also the location & composition of the product development teams. Coordination underlies many of the management problems in designing production rapidly and effectively (Eppinger, 2001).

The Figure 8, given below, presents organization-wide structure-based project strategies used for their Concurrent Engineering (Overlapping Phases) based project for development of 'Edsel Car' in early 1990's (Haddad, 1996).

Figure 8: Platform Team-Structure for Implementation of Concurrent Engineering Approach (Overlapping Development Phases) Used by Ford Motors, USA for 'Edsel Car' Development Project, during early 1990s (Haddad, 1996)



CONCLUSION REMARKS

The proposed research study will be relevant and useful to:

a) Engineering organizations from developing economy, like India, intending to develop new products for competitive globalized markets.

b) Engineering Organizations intending to adopt Overlapping Development Process for integrated design, fabrication, test & trials, and production; and particularly those interested in using CAD/CAE/CAM based design process for virtual assembly & testing, and rapid prototyping.

c) Researchers and academicians interested in pursuing integrated product development in highly dynamic and competitive environment.

REFERENCES

1. Cooper R G (1994), "Debunking Myths of New Product Development", *Research-Technology-Management*, pp. 40-51.
2. Cooper R G (2004), "Pre-Development Activities Determine New Product Success", *Industrial Marketing Management*, Vol. 27, No. 2, pp. 237-248.
3. Cooper R G (2007), "Managing Technology Development Projects", *IEEE Engineering Management Review*, Vol. 35, No. 1, pp. 67-76.
4. Danilovic M and Browning T R (2007), "Managing Complex Product Development with Design Structure Matrix and Domain Mapping Matrices", *International Journal of Project Management*, Vol. 25, No. 4, pp. 300-314.
5. Desai A and Mital A (2011), "Simplifying the Product Maintenance Process by Building Ease-of-Maintenance into the Product Design", *International Journal of Industrial and System Engineering*, Vol. 9, No. 4, pp. 434-457.
6. Eisenhandt K M and Tabrizi B N (1995), "Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry", *Academy Management Journal*, Vol. 32, No. 3, pp. 543-576.
7. Flint D J (2002), "Compressing New Product Concept-to-Delivery Cycle-Time: Deep Customer-Value Understanding and Idea Generation", *Industrial Marketing Management*, Vol. 31, No. 4, pp. 305-325.
8. Ford D (1988), "Develop Your Technology Strategy", *Long Range Planning*, Vol. 21, No. 5, pp. 44-51.
9. Gulati R (2007), "Silo Busting: How to Execute on the Promise of Customer Focus", *Harvard Business Review*, pp. 98-108.
10. Hsu Yen (2013), "Marketing Strategy and its Correlation with Design Strategy and Design Characteristics: An Example of Consumer Electronic Industry", *International Journal of Business and System Research*, Vol. 7, No. 4, pp. 436-451.
11. Hull F M, Collins P D and Liker J K (1996), "Composite Forms of Organization as a Strategy for Concurrent Engineering Effectiveness", *IEEE Transactions on Engineering Management*, Vol. 43, No. 2, pp. 133-142.

12. Joglekar N R, Yassine A A, Eppinger S D, and Whitney D E (2001), "Performance of Coupled Product Development Activities with a Deadline", *Management Science*, Vol. 47, No. 2, pp. 1605-1620.

13. Krishnan V (1996), "Managing the Simultaneous Execution of Coupled Phases in Concurrent Engineering Projects", *IEEE Transactions on Engineering Management*, Vol. 43, No 2, pp. 201-217.

14. Lansiti M (1995), "Shooting the Rapids: Managing Product Development in Turbulent Environment", *Oliverwright Publication Inc, Essex, Junction*.

15. Loch C H and Terwiech C (1998), "Communication and Uncertainty in Concurrene Engineering Projects", *Management Science*, Vol. 44, No 8, pp. 1032-1048.

16. Lynn G S and Akgun A E (2000), "A New Product Development Learning Model: Antecedents and Consequences of Declarative and Procedural Knowledge", *International Journal of Technology Management*, Vol. 20, No. 5/6/7/8, pp. 490-510.

17. Prencipe A and Tell F (2001), "Inter-Project Learning: Processes and Outcomes of Knowledge Codification in Project Based Firms", *Research Policy*, Vol. 30, No. 4, pp. 1373-1394.

18. Rosenthal E S (1998), "What We Have Learnt - Managing Invention and Innovation", *Research-Technology-Management*, Vol. 31, No. 1, pp. 11-29.

19. Schilling M A and Hill C W L (1998), "Managing the New Product Development Process: Strategic Imperatives", *Academy of Management Review*, pp. 436-459.

20. Sung T J and Wu C S (2011), "The Effects of Design Integration Mechanism on the Maturity Levels of a Collaborative Design Team", *International Journal of Networking and Virtual Organizations*, Vol. 9, No. 4, pp. 367-381.

21. Tennant C and Roberts P (2001), "A Faster Way to Create Better Quality Products", *International Journal of Project Management*, Vol. 19, No. 4, pp. 353-362.

22. Thomke S H (2001), "Enlightened Experimentation - The New Imperative for Innovation", *Harvard Business Review*, pp. 67-75.

23. Ulwick A W (2002), "Turn Customer Inputs into Innovation", *Harvard Business Review*, pp. 91-97.

24. Watanbe K (2007), "Lessons from Toyota's Long Drive", *Harvard Business Review*, pp. 74-83.

25. Xiaopeng Li, Mique Zhao and Wei Wang (2012), "Model and its Applications of 7-Design Planning of Product-Design", *International Journal of Materials and Product Technology*, Vol. 45, No. 1/2/3, pp. 191-202.