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Design for Manufacturability and Concurrent Engineering for Product Development

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Abstract**—**In the 1980s, companies began to feel the effect of three major influences on their *product development*: newer and innovative technologies, increasing product complexity and larger organizations. And therefore companies were forced to look for new product development methods. This paper tries to focus on the two of new product development methods (DFM and CE).

The aim of this paper is to see and analyze different product development methods specifically on Design for Manufacturability and Concurrent Engineering. Companies can achieve and be benefited by *minimizing product life cycle, cost and meeting delivery schedule.* This paper also presents *simplified models* that can be modified and used by different companies based on the companies' objective and requirements.

Methodologies that are followed to do this research are case studies. Two companies were taken and analysed on the product development process. Historical data, interview were conducted on these companies in addition to that, Survey of literatures and previous research works on similar topics has been done during this research. This paper also tries to show the implementation *cost benefit analysis and tries to calculate the implementation time.*

From this research, it has been found that the two companies did not achieve the delivery time to the customer. Some of most frequently coming products are analyzed and *50% to 80 %* of their products are not delivered on time to the customers. The companies are following the traditional way of product development that is sequentially design and production method, which highly affect *time to market.* In the case study it is found that by implementing these new methods and by forming multi disciplinary team in designing and quality inspection; the company can reduce the workflow steps from *40 to 30*.

Keywords**—**Design for manufacturability, Concurrent Engineering, Time-to-Market, Product development.

I. Introduction

DESIGN *for manufacturability (DFM)* is the process of proactively designing products to: a) optimize all the manufacturing functions: fabrication, assembly test, procurement, shipping, service, and repair; b) assure the best cost, quality, reliability, regulatory compliance, safety, time to market, and customer satisfaction; and c) ensure that lack of manufacturability doesn't compromise functionality, styling, new product introductions, product delivery, improvement programs, strategic initiatives, and unexpected surges in product demand [5].

Concurrent engineering (CE) is the practice of concurrently developing products and their design and manufacturing processes. If existing processes are to be utilized, then the product must be design for these processes. If new processes are to be utilized, then the product and the process must be developed *concurrently*. This requires knowing a lot about manufacturing processes and one of the best ways to do this is to develop products in multifunctional teams. DFM and CE are proven design methodologies that work for any size company [2]. Early consideration of manufacturing issues shortens product development time, minimizes development cost, and ensures a smooth transition into production for quick time to market.

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II. Myths and Realities of Product Development

Myths of product development

1. To develop products *quicker*, get going soon on the detail design and software coding and then enforce deadlines to keep design release and first-customer-ship on schedule.
2. To achieve *quality*, find out what's wrong and fix it.
3. To *customize* products, take all orders and use an *ad hoc approach:* marking up the existing drawings, or having a separate engineering group perform custom engineering on individual products as needed.
4. *Cost* can be easily reduced by cost reduction efforts after the product is designed [5]

Realities of Product Development

1. The only measure of *time-to-market* is the time to stable, trouble free production and that depends on getting the design right the first time.
2. The most effective way to achieve *quality* is to design it in and then build it in.
3. The most effective way to *customize* products is by the concurrent design of versatile product families and flexible processes, which is known as mass customization.
4. *Cost* is designed into the product, especially by early concept decisions, and is difficult to remove later.

III. When Cost is Committed

Fig. 1 shows that by the time a product is designed, 80% of the cost has been determined [4]. And by the time a product goes into production, 95% of its cost is determined, so it will be very difficult to remove cost at that late a date. The most profound implication for product development is that 60% of a product's cumulative lifetime cost is committed by the concept/architecture phase! This is why it is important to fully optimize this phase.

The Toyota philosophy confirms this. ''The cost of a [product] is largely determined at the planning and design stage. Not much in the way of cost improvement can be expected once full-scale production begins.'' ''Skillful improvements at the planning and design stage are ten times more effective that at the manufacturing stage.''

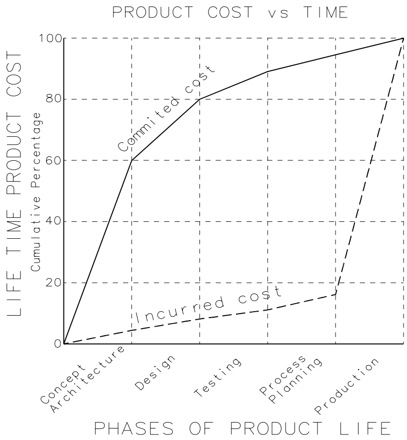

Fig. 1 When cost is committed

Time-to-Market: Time-to-market is a major source of competitive advantage. In fast moving markets, being first to market can have major market share implications. Fig. 2 shows the effect of an early product release on the revenue profile. The shaded area represents the extra sales due to the early introduction. But, since the product development and tooling costs were paid for by the base line sales profile, the shaded area is really extra profit.

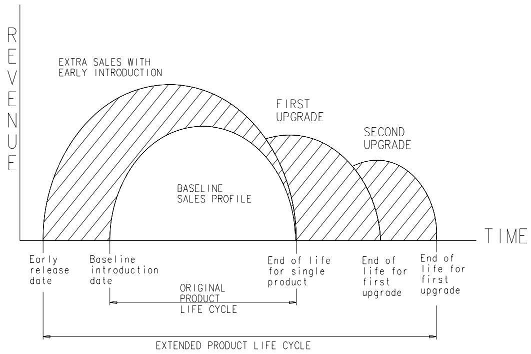

Fig. 2 Increasing revenue with early introduction and upgrades

IV. How to Cut in Half, the Real Time-to-Market

Time to market is heavily affected by early optimization of the early concept/architecture phase as shown by the Lexmark model in the following Fig. 3. The projected 40% savings in the real time-to-market comes from thorough concept/architecture optimization that minimizes the need for revisions and iterations and makes the manufacturing ramp-up much faster. Note that the architecture phase, labelled ''conceptual design'' went from 3% in the old model to 33%(of the total development time) in the new model, an order of magnitude increase! The more thorough up front work decreased the post-design activities (the revisions, iterations and ramp-up) from almost three-fourths to less than a half of the product development cycle. It is more efficient to incorporate a balance of design considerations early than to implement the later with changes, revisions and iterations.

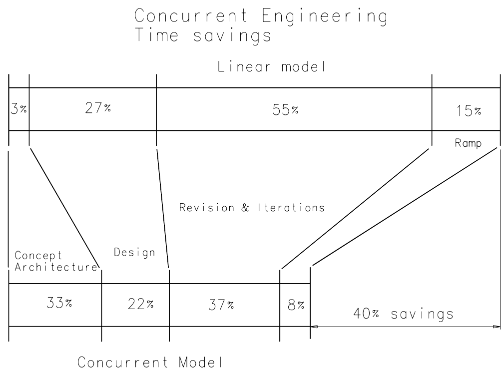

Fig. 3 The Lexmark Model True Time to Market differences between linear vs. Concurrent Models. Case study in Mentor graphic

Product innovation and speed of development are becoming increasingly important in our global economy. Although the role of the product manager in new product development will vary by company, the product manager at minimum should take care in understanding and articulating the market potential and in participating on the product development team. Note that the first step of the new product development process is idea generation [11]. Ideas are fleshed out into a proposal and presented to top management (or a new-product review committee comprised of key executives of all the functional areas) for screening.

For major product ideas/ concepts that pass screening, management assigns representatives from relevant functional areas to a multifunctional project team for this particular new product endeavour. The team members select a leader (who might or might not be the product manager) to organize and monitor the project, guiding it through the critical path schedule developed by the team. All members do as many tasks as possible in parallel (concurrently) to shorten the product development cycle. For example, product managers can conduct focus groups on concept evaluation at the same time that engineering is conducting technical feasibility studies. The dotted line from the concept development and evaluation box to project cancellation box indicates that

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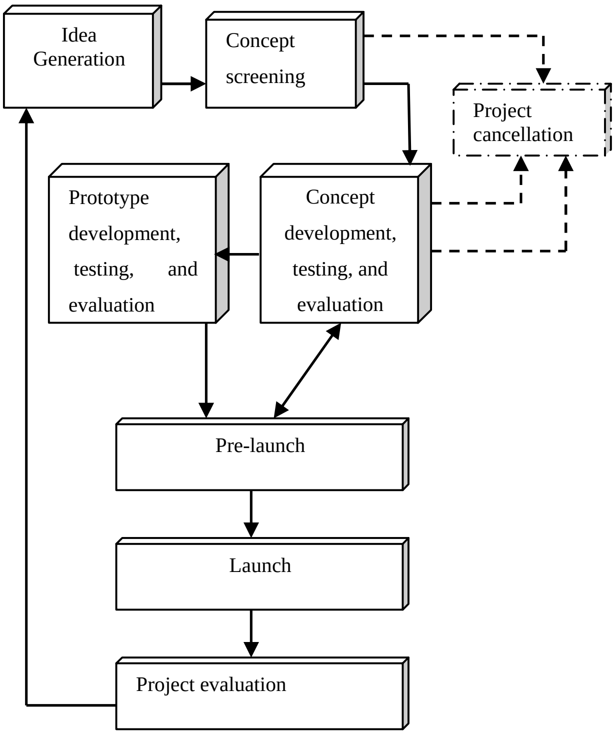

Fig. 4 New product development flow chart

Concepts testing poorly should be considered for elimination as early as possible rather than investing more resources in their development. In general, the stages of new product development can be summarized in the following table.

STAGE	DESCRIPTION	RESULT/OUTPUT
Idea generation	Creation and data basing of ideas	New product proposal
Screening	Examination of ideas along pre-established criteria	Assignment of project team
Concept development, testing and evaluation	Refinement of product concept, estimation of customer interest, augmentation of business analysis (financials), go no go decision	Detailed product, market, financial and project plans, product specifications
Proto type development, Testing and evaluation	Physical development of product in R&D; functional and customer testing of the actual product	Final changes to product specifications and production plan
Pre-launch	Development of launch strategy; if necessary, market test or simulated market test; initial sales	Finalization of launch document; completion of product training, product support plans, sales collateral, and related written communications
Launch	Introduction and marketing of product as detailed in the launch strategy document	New-product launch
Project evaluation	Comparison of results to initial objective	Suggested improvements for future projects

Fig. 5 Stages in new product development

There is increased pressure to get products of ever-higher quality to customers in ever-shorter times. Product life cycles are decreasing as well, and product price/ performance ratios are being scrutinized more carefully. The traditional ‘‘serial’’ approach to product design and development (see Fig. 3) used by many companies today is, therefore, hampering their ability to compete effectively in what is becoming an increasingly global market place for electronic (and other) products.

In serial Engineering environment, design is often done in a relative vacuum [9]. Manufacturing, test, quality and service organizations may not see a design until it is virtually completed. If they raise points during design reviews regarding the difficulty, time, and expense involved in producing the design as presented, they may cause the need for the product to be redesigned.

If a redesign is too expensive or too time consuming, no action will be taken to improve the manufacturability, testability, quality, or serviceability aspects of the product, and it will be more expensive to produce, verify and support than it could (or should) before its entire life. All of these factors hamper competitiveness.

One solution to improving competitiveness is to change from a serial design and development process to a concurrent engineering process (see Fig. 3). The concurrent engineering process treats design for manufacturability, testability, quality, and serviceability attributes (among many others) equally and in parallel with product design for performance attributes such as speed, power consumption, size, weight and reliability. Concurrent engineering integrates the expertise from all of the various engineering disciplines during the actual design phase [8] and the whole focus of concurrent engineering is on a ‘‘right-the-first-time’’ process, rather than on the typical ‘‘redo-until-right’’ process that is so common in the serial engineering mode of operation. The elimination of design iterations reduces product development costs and shortens time to market for new product

V. Case Study One

For this particular research, 15 items, which are frequently coming to AEC for the last 5 years, is selected and analyzed. By looking only number wise; out of 15 items, only four are delivered to the customers on time and the rest (11) are delayed due to different reasons, which are indicated on the fish bone diagram on the thesis [1].

The above illustration shows most of the time Addis Engineering Center is not delivering on time for its customers

On time and early delivery $= \frac{4}{15} X100 =$ **26.67%**

Delayed delivery $= \frac{11}{15} X100 =$ **73.33**

TABLE I
SOME OF THE PRODUCTS OF ADDIS ENGINEERING AND PRODUCTION TIME

NO.	ITEMS	QTY	ACTUAL TIME (HRS.) TOTAL	ESTIMATED TIME (HRS.)	TOTAL EFFECT (HRS)
1	Swash plate	2	58	40	18 (delayed)
2	Template	6	183	258	75 (early)
3	Spinning disk	1	12	19	7 (early)
4	Punch	1	14:30	8:30	6(delayed)
5	Spline bushing	1	28	12	16(delayed)
6	Worm shaft	1	7	12	5 (early)
7	Compression spring	500	267	82	185(delayed)
8	Plug gauge	40	290	146	144 (delayed)
9	Bend wire guide	8	26	43	17 (delayed)
10	Bending die	1	37	27	10(delayed)
11	Helical gear	2	26	41	15 (early)
12	shaft	1	62	52	10 (delayed)
13	First male die	1	65	37	28(delayed)
14	Horse shoe gauge	1	50	27	23(delayed)
15	Female die	5	167	170	3 (early)

Fig. 6 Graphical representation of delivery delay in Addis Engineering Center

Most customers bring different type of components, which are not in the form of assembly or as a set. Few customers come with components, which require a skill of group technology, which minimizes production time more specifically set up time of the production processes. From the last five years experience, dies are repeatedly coming from different factories and institutions to Addis Engineering Center. Irrespective of their shapes and dimensions or sizes with an average of 15 dies are ordered to be manufactured in AEC. On manufacturing the dies, male die and shank holder could not produced in parallel because it violet design for assembly. Similarly, lower dies and strippers are produced one after the other. The rest components can be produced in parallel so that the production time can be minimized.

TABLE II
ITEM WHICH IS MANUFACTURED AS A SET OR ASSEMBLY IN ADDIS ENGINEERING CENTER

Items	**QTY**	**Actual time (hrs.) per pc**	**Estimated time (hrs.) per pc**	**Effect**	**Total effect Per Pc.**
Male die	15	7	7:30	0:30(early)	7:30
Shank holder	15	5	4	1 (delayed)	15
Longer Bolt	15	6	3	3 (delayed)	45
Punch guide	15	13	11	2 (early)	30
Base plate	15	15	12	3 (delayed)	45
Shorter bolt	15	2	4	2 (early)	30
Spacer	15	9.30	14	4:30 (early)	67:30
Punch holder	15	9	8	1(delayed)	15
Punch (Big)	15	9	9	on time	0
Lower die	15	13	11	2 (delayed)	30
Stripper	15	8	6	2	30

TABLE III
CAUSES FOR DELIVERY DELAY AND FREQUENCIES IN ADDIS ENG.

S/n	**Delivery delay causes in AEC**	**Frequencies in year (E.C)**			**Average (three years)**
		1996	**1997**	**1998**	
1	Modification of cutters	34	40	38	37.33
2	Availability of ample Raw material	32	28	30	30
3	Incomplete information from customer	24	20	16	20
4	Maintenance of machines & equipments	20	15	13	16
5	Negligence of operators	16	8	18	14
6	Manufacture indirect measurement	8	10	18	12
7	Social factors	10	14	12	12
8	Special work holding device	12	5	13	10
9	Heat treatment delay	10	6	8	8
10	Mismatch of capacity& availability	2	4	6	4

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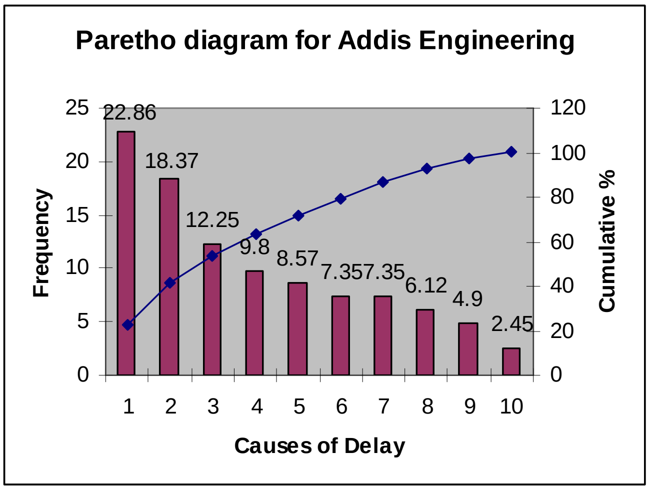

Fig. 7 Paretho analysis of Addis engineering

Interpretation of the Pareto Curves

It is important to identify the vital few from the trivial money and the paretho analysis is a tool, which is implemented to this research. A useful first step is to draw a vertical line from the **20- 30** percent area of the horizontal axis.

These are often called the **vital few**, which have been highlighted for a special attention. It is clear that, if the objective is to reduce delay in delivering to the customers, the company should pay attention and eliminate the prolonged time spent modification of cutter and should have proper inventory control and supply system so that the raw materials are supplied on time with the required specifications.

VI. Case Study Two

Dejen aviation maintenance and engineering complex is the second company for this research that it faces a delivery delay. As it is seen from the above data, one can reach to a conclusion that DAMEC has also a problem on delivering products on time. Mathematically it is possible to put the result as follows:

Products delayed on delivery = $\frac{31}{55}$ X 100 = 56.36 %

Early completed jobs = $\frac{12}{55}$ X 100 = 21.85 %

WIP and Items not recorded = $\frac{8}{55}$ X 100 = 14.54 %

Products completed on time = $\frac{4}{55}$ X 100 = 7.27 %

TABLE IV
Causes for Delivery Delay and Frequencies in Dejen Avia

S/N	DELIVERY DELAY CAUSES (DAMEC)	AVERAGE (THREE YEARS) FREQ.	CUM.FRE.
1	Availability of ample Raw material	33.05	33.05
2	Incomplete information from customer	20.66	53.71
3	Modification of cutters	14.87	68.58
4	Maintenance of machines & equipments	9.9	78.48
5	Negligence of operators	6.6	85.08
6	Manufacture indirect measurement	4.98	90.06
7	Special work holding device required	3.3	93.36
8	Social factors	3.3	96.66
9	Heat treatment delay	1.65	98.31
10	Mismatch of capacity& availability	1.65	100

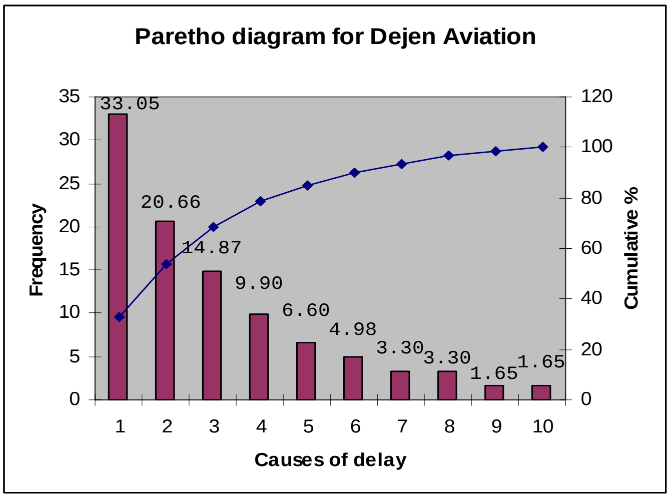

Fig. 8 Paretho analysis of Dejen Aviation

The Paretho analysis in Dejen Aviation Maintenance and Engineering Complex shows the vital few are availability of ample and quality raw materials and incomplete information that are coming from different departments. By avoiding the problems (delays) caused by these factors, it is possible to minimize the delivery delay, which in turn affects the performance of the company. This and other process like assembling and repairing have direct impact on the overhauling processes of the aircraft.

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DESCRIPTION	D1	D2	D3	D4	ESTIMATED COST
Preparation Phase workshop on concurrent engineering by external professionals for Top management	21 days				Training cost, lost time of 30 persons @120 birr per person per day =75,600 birr
CE steering committee formation from TOP management team					
CE attitude survey (profile of organization, quality costs, organization strength/weakness, advocators & resistors.					
Planning Phase Strategic planning workshop (By CE steering committee): Create vision, guiding principles, set broad strategic objectives, develop quality policy, identify critical success factors& critical processes, baseline employee satisfaction and customer satisfaction.		10 days			Workshop running expenses, lost time of 30 persons @100 birr per person per day, =30,000 birr
Plan the implementation approach and asses the implementation guide.					
Execution Phase Form multidisciplinary teams/site steering committees from each department and identify team facilitators.			70 days		For 60 Lost time@70birr per person per day, training costs, Lost services because of inefficiency during first months, 294,000 birr
Specific training and team-forming workshops for site steering committees.					
Create awareness on customer/ supplier relationship					
Company-wide implementation/improvement projects for CE (CE Value, customer/supplier frame work, systems and techniques).					
Modify infrastructures as necessary (procedures/processes, organizational structure, reward/recognition system, union rules etc.)					
Evaluation Phase Feedback/ follow-up workshops				5 days	10,000 birr
			Total	106 days	409,600 birr

Fig. 9 Concurrent engineering Implementation plan in Addis engineering

TABLE V
MONETARY BENEFIT OF CONCURRENT ENGINEERING IMPLEMENTATION

S.N	BENEFIT OBTAINED FORM CE	ESTIMATED VALUE OBTAINED (BIRR/YEAR)
1	Increased revenue generation	150,000
2	Benefit from Elimination of delivery delay	100,000
3	Better employee participation and communication	50,000
4	Elimination of redesigning process	100,000
5	Improved customer service and reducing the scrap	50,000
6	Better ability to manage new product development	50,000
	Total	500,000

Total benefit obtained is 500,000birr per year
Total cost required to implement Concurrent engineering is 399,600 birr

$$\text{Payback period is} = \frac{409{,}600}{500{,}000} \text{ year} = 0.8192 \text{ year.}$$

It is approximately 10 months.

VII. CONCLUSION

Success in manufacturing requires continuous development and improvement of how the products are developed and produced. This paper is done taking two manufacturing companies as a cases tudy. The study depicted or assessed in Addis Engineering center and Dejen Aviation Maintenance and Engineering complex and find out these companies did not achieve the delivery time to the customer. Some of most frequently coming products are analyzed and 60 to 80 % of these products are not delivered on time to the customers.

The companies are following the traditional way of product development that is sequentially design and production method, which highly affect time to market. Time is very important consideration in concurrent engineering. The long workflow of Addis Engineering Center has its influence for the customer requirements on the eyes of achieving the delivery time. By forming multi disciplinary team in designing and quality inspection, the company can reduce the workflow steps from 40 to 30. This in turn reduces the average time for production of a single product from customer order to the delivery of finished products.

The paper tries to show the most common types of activities that affect the production process in AEC and DAMEC. Identifying the types and depths of activities helps the companies to take the remedial action by prioritizing the most occurring and influential ones through production and new product development processes. Concurrent Engineering is not a quick fix for a company's problems. It is a business strategy addresses important company resources. The major objective

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this business strategy aims to achieve is improved product development performance. Concurrent Engineering is a long-term strategy, and it should be considered only by organizations willing to make up front investments and might need years for long-term benefits. The implementation guide, which is presented in this paper, is simplified and can be implemented with out sophisticated software applications in different industries. This could be achieved by forming multi disciplinary team.

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