Title: Concurrent Engineering in Product Design Decisions and Proposed Economic Evaluation Model.

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Author(s): J. Alvarez

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# Concurrent Engineering in Product Design Decisions and Proposed Economic Evaluation Model

J. Alvarez

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ENGINEERING ECONOMIC ANALYSIS EMGT 535

# RESEARCH PAPER: CONCURRENT ENGINEERING IN PRODUCT DESIGN DECISIONS AND PROPOSED ECONOMIC EVALUATION MODEL

PRESENTED TO: DR. DICK DECKRO

BY: JOHN ALVAREZ

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## Introduction

In this research paper we present the concept of concurrent engineering, some areas in which it is currently applied, its importance in engineering management, and its application in product design decisions with a proposed economic evaluation model.

## Concurrent Engineering Philosophy

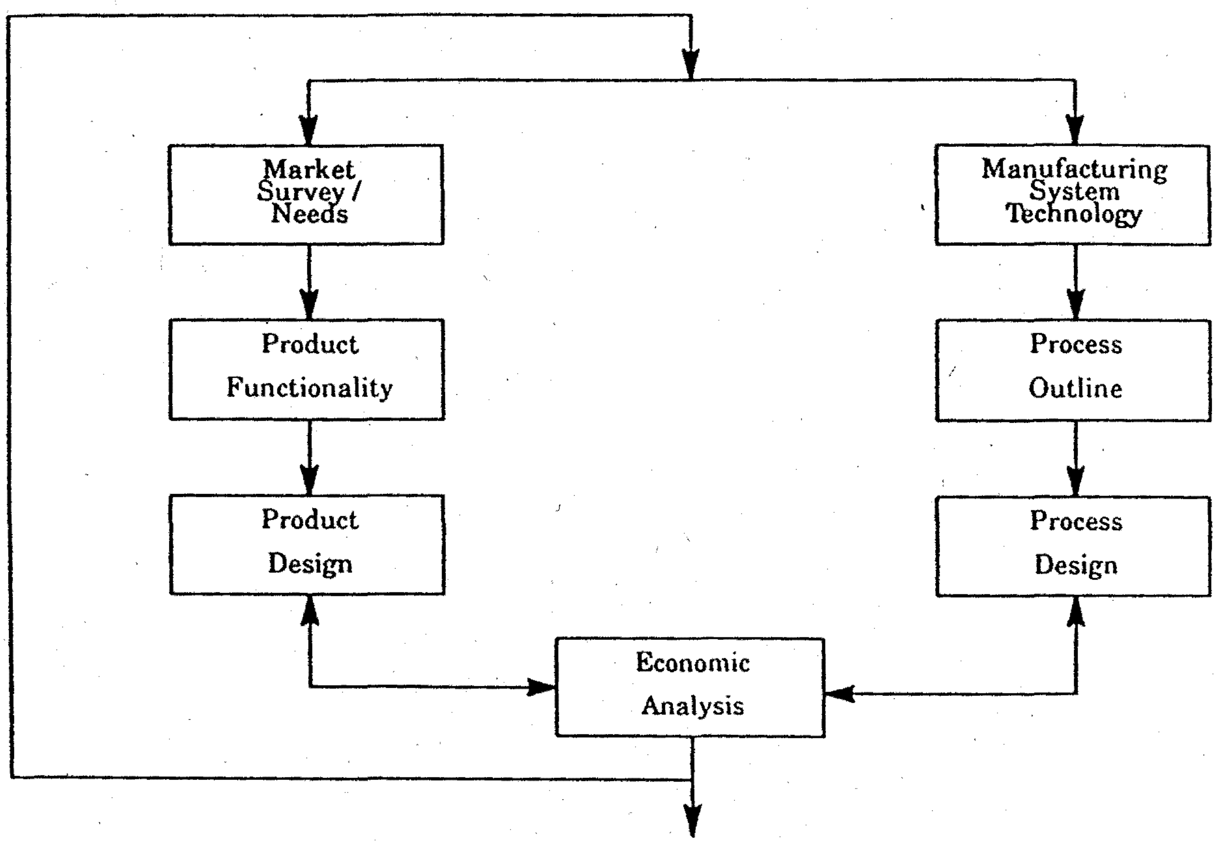
Creese and Moore (1) define that concurrent engineering is a management and engineering philosophy for improving quality, reducing costs, and reducing the lead time from product conception to product development for new products and product modifications. It emphasizes management as well as engineering skills and requires multidirectional information flow. A major difficulty in the implementation of concurrent engineering is the failure of management to recognize that this philosophy must be implemented at the top level's first. This philosophy further on must be implemented differently for different companies because of variations in leadership styles, products, processes, employee abilities, customer requirements, and supplier capabilities.

Another similar definition of concurrent engineering is that it is the process of planning and executing product design and manufacturing simultaneously, with strong cross --functional participation. Emphasis is put on increased quality, speed and cost - effectiveness. (2)

More specifically, concurrent engineering is the state that product and process design are developed simultaneously together wit an economical analysis. ( 4) See figure

## Importance of Concurrent Engineering Philosophy

**Figure 1.** Information flow in concurrent design of product and process.



Concurrent engineering philosophy has become incorporated in many technologically driven companies in their product design teams. When this philosophy is applied the team becomes a focal point for the simultaneous rather than sequential product design process. This simultaneous design process often reduces the time between conception of a product/ process idea and its introduction into the market. In these teams different individuals are brought from different areas of the company like R&D, Design, Engineering, Manufacturing, Marketing, Purchasing and other functional groups to work in the development of a specific product or process. The concurrent philosophy implementation in the product design team thus reduces the barriers between these functional groups, and increase the effectiveness of the technology transfer and management process.

The use of design teams as a focal point to integrate the concurrent design of product and process technology is a relatively new approach. Early returns on the results of using concurrent engineering within the context of product design team have been striking. Shorter schedules for conceptualization, design, manufacture, and marketing of products is particularly advantageous considering speed has become a key to global market competitiveness. (3)

Manufacturers also have reported that they realized remarkable benefits by implementing concurrent engineering in the following areas:

Manufacturing cost reduction,

Engineering change order reduction by improved design quality,

Scrap and rework reduction,

Product development time reduction,

Product quality improvement by defect reduction,

Product quality improvement by defect reduction, and

Savings below bid(4)

Economic Evaluation of Benefits Of Concurrent Engineering

The justification of concurrent engineering benefits through economic measurement has not been fully performed. New cost estimating and economic analysis techniques are required since conventional cost systems are no longer appropriate to accommodate concurrent engineering practices in advanced manufacturing systems.

Concurrent engineering is one of many models suggested in recent years for planning and implementing organizational changes in moving toward quality and productivity improvement. All these models emphasize, key management issues confronting executives today like improved quality, flexibility, speed and creativity. These new approaches require a revision of traditional economic justification methodologies. When put to the test the traditional economic justification methodologies may have inadequately evaluated investment proposals and consequently slowed the growth of possible solutions such as flexible manufacturing systems.(5)These traditional economic justification methodologies fail because they do not show the benefits of improved quality, flexibility or productivity.

To cope with these limitations some economic models have been proposed. Blank (6) provides some general discussion of generic considerations when evaluating manufacturing systems based on the discounted cash flow model (DCF). Primrose and Leonard (7) developed a new appraisal technique based upon a series of computer programs. Fisher and Hof (8) develop an expert system that helps in cash flow estimation. Myers(9) provides some notes on capital investment evaluation involving expert systems.

Ozzone and Bertele (10) build a model based on concepts of Primrose and Leonard (7) and Suresh and Meredith(11) in order to evaluate the economic impact of manufacturing systems flexibility. To do this they merge a multiattribute evaluation of the firm's strategic performance requirements and flexibility considerations with a DCF.

Azzone and Bertele's model give four performance indicators that characterize the firm's strategic position that is: (1) response time, (2) probability of meeting that response time, (3) probability of a new product's introduction, and (4) probability of being able to produce that new product with the existing manufacturing system. In their model flexibility consists of six dimensions: routing, process, product, production, volume and expansion. Through four such models they develop a stochastic product mix, determine machining times, machining tools and number, and finally link the results in a DCF model involving revenues, costs and investments.

Son and Park develop performance measures based on partial measures for productivity, flexibility and quality. These partial performance measures are then used in a simulation to compare a hypothetical flexible manufacturing system and a job shop. (12)

In their work Son and Park address deficiencies of the traditional methods of cost accounting and specify that conventional cost methods don't show the substantial benefits of advanced manufacturing techniques. Further on they formulate a multistage investment decision model that considers this non conventional costs.

In this model, Park and Son develop a mutiperiod net present value linear programming model that incorporates measures of productivity, quality and flexibility .In their work they replace conventional accounting income and expense classification with a classification that they claim breaks out costs more distinctly.

On the basis of the model he developed with Young K. Son's, Chan S. Park develops a model with Chi J. Oh was they propose an integrated design decision model in which decisions on product and process designs are simultaneously performed through economic evaluation at each stage of decision making. In this paper we will focus on the process developed in this work.

Chi J. Oh and Chan S. Park Economic Evaluation Model for Product Design Decisions Under Concurrent Engineering

As stated before, in their work, Chi J. Oh and Chan S. Park develop a multistage integrated decision model in which decisions on product and process design are simultaneously made at each stage. As a solution procedure they use a dynamic programming method to obtain the optimal design decision that minimizes total costs under strategic constraints. Finally they present an application of the proposed model with the solution procedure to a printed circuit board (PCB) designing and manufacturing company to show the effectiveness of concurrent design of process and product.

Integrated Model

The modeling procedure of the multistage integrated decision model is outlined as follows:

Step1. Establishing Product Design Alternatives

A product design alternative is one of many preliminary product design proposals passed to the joint team of product and process design for initial evaluation.

Step2. Establishing Process Design Alternatives

The entire manufacturing process necessary to yield the designed product are divided into several key operations and for each key operation different alternatives are proposed.

Step3. Performance Measuring

Some key measures relevant to the system behavior are define and quantified.

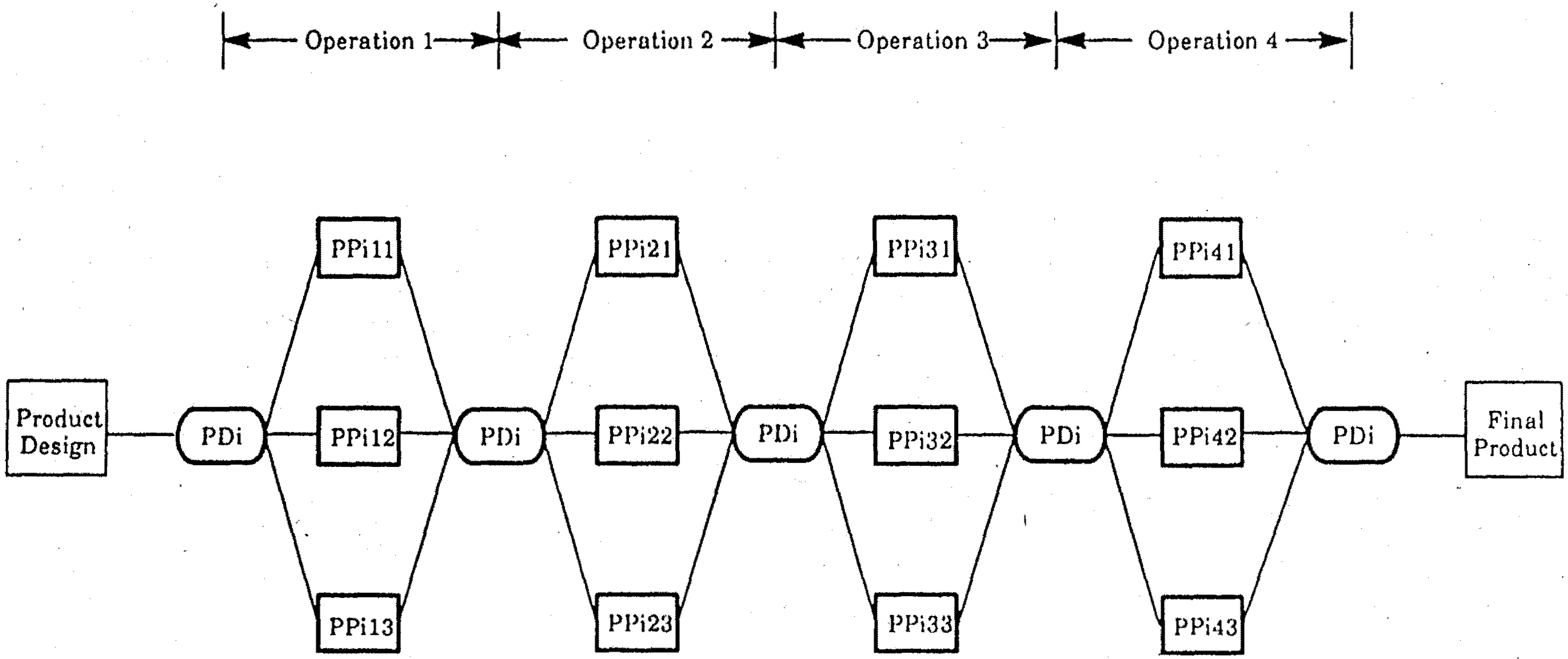



**Figure 2.** A multistage integrated decision model.

Step4. Cost Estimating

The cost classifications are redefined to support concurrent engineering benefits.

Step5. Determining Optimal Design Decision

Using a dynamic programming method the optimal design alternative is selected at each stage of operation in manufacturing flows and finally the optimal product design alternative with the minimal product cost under strategic constraints is selected.

In the schematic diagram of the multistage integrated decision model the entire manufacturing process is divided into four key operations (operation 1 through 4 ) and each process divided into three process design alternatives (PPij1 through PPij3). The economic evaluation data set including performance measures and cost estimates for each PPijk is obtained. For each product design alternative the optimal path of process design alternatives is obtained through a dynamic programming method. Finally the optimal product design alternative is selected.

Economic Analysis of Integrated Model

In the integrated model new techniques of performance measuring and cost estimating are developed to reflect the benefits of concurrent engineering.

Performance Measuring

In the integrated model the key measures are time -related measures(throughput time of each process alternative to obtain final production cycle from product design concept to market availability), quality --

related measure (number of non conforming items out of a fixed lot size), and inventory related measure ( inventory turn over ratio )

## Cost Estimating

In the proposed model, the total manufacturing cost that is a major component of the product cost is classified into four major categories : Productivity, quality. flexibility and inventory. Each of these categories is later on subdivided into various cost elements. ( See figure )

The productivity cost in the model includes the costs of labor, material and machine, and some overhead items all of which are required for the value added activities of manufacturing operations.

The quality cost in this model is classified in four subcategories: Prevention, appraisal. internal failure and external failure.

The flexibility cost in this model includes set up costs. and idle costs

The inventory cost is divided into ordering cost, storage cost, waiting cost and shortage cost.

## Solution Procedure

The solution procedure of the proposed model follow the general feature of the dynamic programming method.

### - Establishing Parameters

To solve a dynamic programming method the following parameters are established:

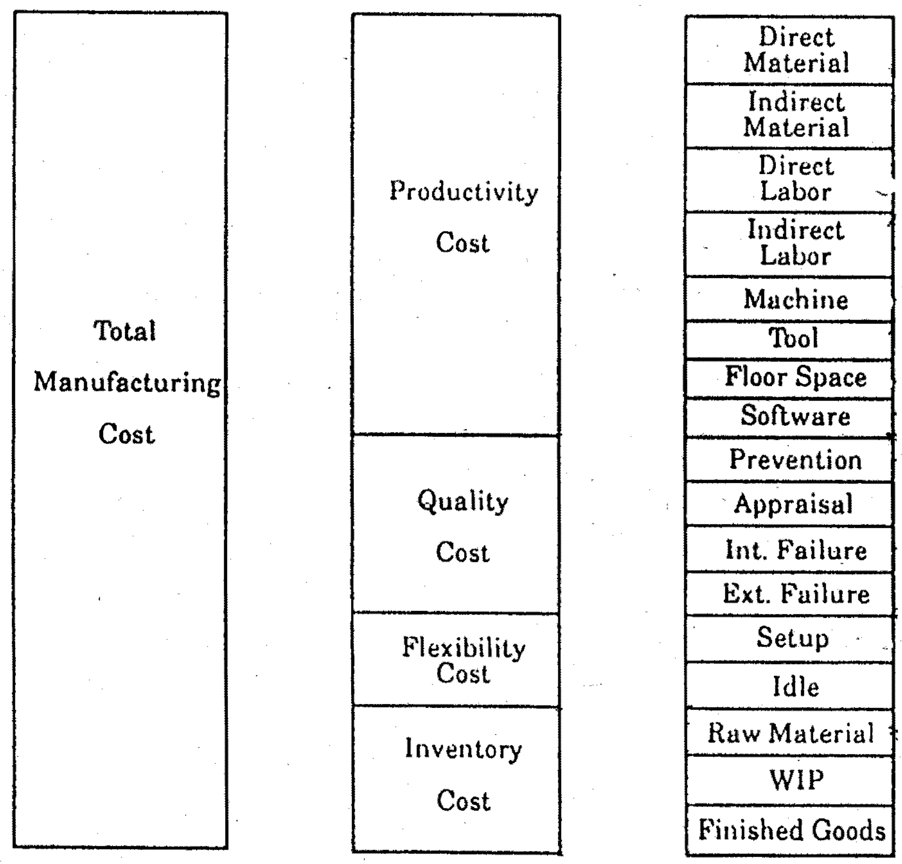
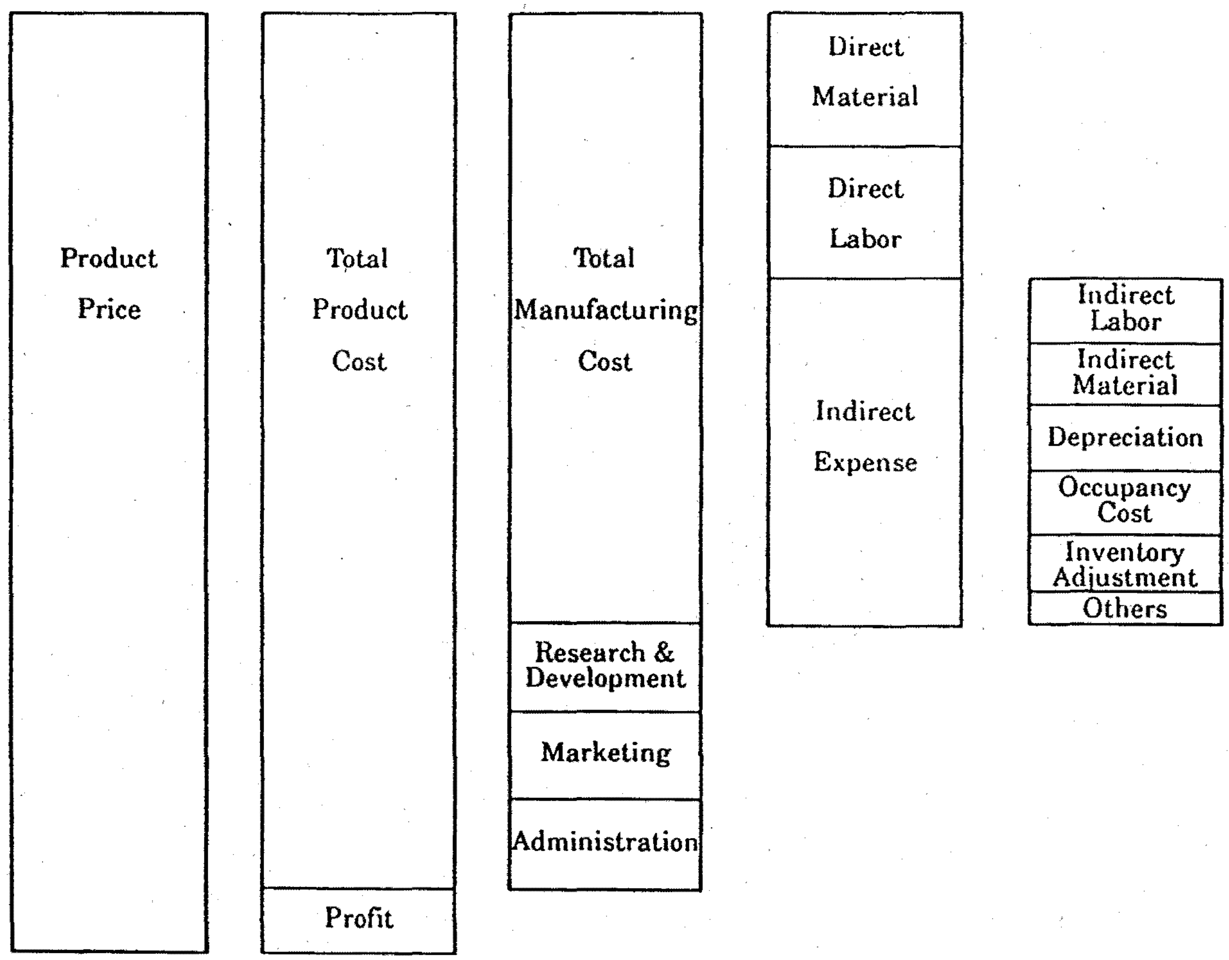



**Figure 4.** Reclassification of manufacturing cost proposed in this model

Figure 3. Conventional classification of product cost.



- Stages: Key operations decomposed from the entire manufacturing processes.

- State Variables: The state variables include performance measures as maximum allowance of production cycle time, the maximum allowance of defective items, or company's target level of inventory.

- Decision Variables : At each stage of key operations, the decision is made on which process design alternative should be selected.

- Return Function: The return function at each stage of a key operation is the production cost required to process a unit of product using each process alternative.

_ Transition Function: The transition function varies depending upon the nature of the state variables.

Solution Technique

At each stage we determine the decision variable to minimize the accumulated return function for all possible values of the state variables.

Case Example

The authors apply this proposed model to a company that adopts concurring engineering to integrate the area of design, manufacturing and management in the development of a new product that is going to be introduced into the market. The company manufactures PCB's in its plants.

The model is applied and it was found that the manufacturing cost measured by the proposed cost system tracked the operating benefits of concurrent engineering and reflected the major competitive factors such as productivity, quality, flexibility and inventory.

## Conclusions

The model proposed by Chi J. Oh and Chan S. Park shows the benefits of adopting concurrent engineering but is difficult to implement. Considerable efforts are needed in order to obtain input data, system parameters and other performance data.

The cost reclassification presented , clearly shows the productivity, quality, flexibility and inventory benefits of adopting concurrent engineering .

Further research must be carried on in this direction to simplify the application of this new classification of costs in the economic evaluation of concurrent engineering benefits.

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