Division of Research
School of Business Administration

July 1991

MANAGING DESIGN SYSTEMS IN MANUFACTURING: Preliminary Survey Results*

Working Paper #672

John E. Ettlie
Michael D. Warner
The University of Michigan

Draft: Not to be quoted or cited, without first author's permission.

*Work in this area was funded by the National Science Foundation under grant No. DDM-9007043 and the University of Michigan. The opinions in this report are those of the authors and do not necessarily reflect the official positions of the NSF.

John E. Ettlie, Ph.D., Director, Manufacturing Management Research, School of Business Administration, The University of Michigan, Ann Arbor, Michigan 48109-1234, 313-936-2835.

Michael D. Warner, MBA II, School of Business Administration, The University of Michigan, Ann Arbor, Michigan 48109-1234.

Managing Design Systems in Manufacturing:
Preliminary Survey Results

Contents

Section **Pages**

Executive Summary iii

Acknowledgements iv

1.0 Introduction 1

2.0 Methodology 2

3.0 Results 6

3.1 Changing Nature of the Product Development Process 8

3.2 Benchmarking 16

3.3 Financial Planning 23

3.4 Problems and Prospects for Changing the Product Development Process 24

4.0 Summary and Conclusions 27

Appendix 29

Executive Summary

We surveyed 43 manufacturing companies and divisions to determine the state-of-the-art of product development philosophies, strategies and practices, in U.S. based manufacturing. Respondents were usually middle managers (63%) or top managers (general manager or above, 25%). Although 31 product types were represented, most were in SIC 34-37, which is fabricated metal products, machinery, electrical equipment and transportation equipment (e.g., aerospace, automobiles). Twenty-four of responding firms were in the Fortune 250 and the sample averaged $16 billion in sales.

Results were quite unexpected on several issues. Although all but one of the responding firms said they had a program to upgrade the way they develop products, only a slim majority of these companies (24 or 56%) bench mark on product development processes. What is more, manufacturing almost never gets formally involved in the concept development stage formally, yet this may be the most important part of the product development effort. Cycle time reduction was not only conspicuous by its absence as a driver in product development strategies, it was often mentioned as a barrier rather than a strategic opportunity or target. Merely including time as a trade-off seems inconsistent with the attention this variable is receiving in theory and practice of design today.

In comparing survey results from 1991 with similar (but not identical) firms from another study in 1987, there is good news and bad news. While companies are using more training and development (e.g., design-for-manufacturing) to enhance their design practices, there still appears to be resistance to adopting job rotation among functions. Marketing is still the number one choice function outside engineering for involvement in efforts to integrate design, and quality is second, as in 1987. Firms continue to increase their use of manufacturing sign-off and new structures (e.g., teams) to implement their new product development philosophies.

There continues to be a gap between degreed design versus manufacturing engineers. The average percentage of degreed design engineers in the sample was 74.7% (median=90%), while the average percentage of degreed manufacturing engineers was 61.0% (median = 60%). The average ratio of design to manufacturing engineers was 4.69 to one, whereas this ratio was 2.88 to one in the 1987 survey. That is, there has been no improvement in these ratios.

Although firms are attempting to accomplish multiple purposes with their new design approaches (e.g., cost, quality, timing) only a slightly greater number are using in-process measures (e.g., reduction in design change requests) to monitor their progress towards those goals. In 1987, 13% of the sample used in-process measures, and in 1991, 35% used these same or newer measures (e.g., milepost passage reports).

Not surprisingly, respondents felt that the most important determinant of success in product development was to know your customer and integrate functions. What is more, the absence of good communication and goal clarity were the most frequently mentioned barriers to acheiving high quality designs, quickly.

Acknowledgements

Although this project has just begun, nearly a dozen people have already made contributions to inprocess activities. Team members on the program contributed questions to the preliminary survey and mentoring throughout. This includes Professors Dan Shunk, Peter Hom, Richard Beltramini, and Germain Boer. Members of our partner firm in the aerospace industry have been very helpful in letting us get "close" to the design process and product development in that industry. Their names will not be mentioned here because of the same procedures we used in the mail survey--that is, this work is carried out in confidence.

We thank all the respondents who took time to fill out the questionnaire and for going well beyond our questions with letters and other comments on our work. The issue of product development has become what some people refer to as a "hot topic," but this did not seem to influence survey participants' candid answers or willingness to share information. We are gratified by this response.

Managing Design Systems in Manufacturing: Preliminary Survey Results

1.0 Introduction

In the Summer of 1990 we were granted funds by the National Science Foundation to study the design process in discrete product industries in the United States. The study has two parts. The first part is a demonstration of integrated design with an industry partner. The second, parallel activity, involves documenting the changing nature of the product development process. This is a summary progress report on the latter, and just preliminary mail survey results. A second, completely different survey, for a much wider population of firms is planned for the Fall of 1991.

We assumed, and results confirm that there is significant change afoot in the way American companies design and develop their new products. In particular, there has been a significant increase in focus on the customer and quality in the product introduction process. This should surprise no one reading this report. What is new, and interesting is the way in which firms are doing this. It is hoped that the results of this preliminary survey of the state-of-the-art of product development will shed some light on this question.

The report is divided into five sections, including the introduction. The next section summaries the methodology we used to survey current U.S. practices in product development. Then results are presented and the implications of these results in the conclusions section. Finally, the survey questionnaire, itself, is included in the Appendix.

Much of the work that went into the survey design is based on previous research and cases[1], but these earlier materials will not be dealt with in this summary report with the exception of direct comparisons of frequency distributions from previous (1987) research. The second, more comprehensive survey, which is planned for the fall of 1991, is already being planned and

---

[1] See, for example, John E. Ettlie and Henry W. Stoll, Managing the Design-Manufacturing Process, New York, NY: McGraw-Hill Book Company, 1990.

there are also parallel projects underway, which include a study to compare practices across nations.[2]

2.0 Methodology

Data were collected using a mailed questionnaire (Appendix) which guaranteed confidentiality. That is, no names of companies or individuals would be associated with reported findings. The questions included many that were used in earlier work (see footnote 1) as well as the combined efforts of all members of the NSF project team (see Acknowledgements). The stated purpose of the survey was that it was part of a study to "investigate integrated approaches to design in manufacturing." National Science Foundation sponsorship was indicated and University letterhead was used in all cases with a cover letter for the initial contact.

Population and Sample

The population for the study was defined as all domestic discrete product enterprises and their divisions. The sample was compiled from a cross-section of firms selected from two source lists: portions of the mailing list of firms of The Office of Manufacturing Management Research (OMMR) of the School of Business Administration at the University of Michigan and portions of the list of members of a manufacturing consortium of a not-for-profit organization. Firms or divisions manufacturing discrete parts or products were selected. The firms responding were primarily well known, large enterprises and data were compiled by division. Mean division sales = $16.7 billion (median = 3.4 billion) and mean division number of employees = 77,663 (median = 30,300) - according to Dun and Bradstreet listings 1991 in domestic product industries. Characteristics of the sample second response rate are described below.

---

[2] Ettlie has a grant from the Center for International Business at the University of Michigan to document three case studies of product development in Europe during the Summer and Fall of 1991. Projects are also underway to document costing for design (G. Boer), and the technology of design systems (D. Shunk).

Respondents

As shown in Table 1, a total number of 122 survey questionnaires were mailed starting in November of 1990 and continued through May of 1991. One month after the initial mailing, a sample of nonresponding firms were contacted by phone. After this follow-up, and due to the apparent salience of the topic based on answers to Question 2 of the survey on the prevalence of product program changes, as well as letters and comments, we were able to increase response rate substantially, to 36%. Some follow-up involved the mailing or faxing of a second questionnaire. The total number of written refusals to respond was 3, out of the 122. In addition, two recipients stated in telephone calls that they did not respond to surveys as a company policy, bringing total refusals to five.

At this writing, 43 firms or divisions responded, for a 35% usable response rate. The total number of individual responses, including multiple company responses, was 57%. For every company with more than two responses, the questionnaires represented business units or product lines. These multiple company responses are analyzed separately and discussed in subsequent reports.

Surveys were often passed on to subordinates or to individuals closer to the product development role. A total of 86% of these responses said they were the best person to contact for follow-up and future research. (Question Number 24 in the Appendix). Table 2 summarizes respondents by job title. The person who most commonly responded to the questionnaire was in a middle management position (63%). Examples are: Manager, Product Development; Manager, Process Engineering; Director, Planning; Director, Engineering; Group Director, "Product Type". Yet, almost 25% of the surveys were returned by top management, that is, in positions of General Manager and above.

A considerable variety of industries are represented in the sample. An analysis of companies returning to the questionnaire showed that over 31 product types (4 digit sic codes) were represented, including, auto, aerospace, machine tools, and appliance manufacturers.

Table 1

Product Development
Preliminary Survey Status - Revised 7/11/91

	Mailing Date	Initial Mailing	Initial Response	% Return	Follow-Up Contact	Follow-Up Response	% Return Follow-Up	Individual Total Usable 1	Individual % Return Usable	Multiple Response (Per-Firm)	Firm Total Usable 2	Firm % Return Usable
Manufacturing Consortium	Nov-90	51	8	15.7	16	10	62.5	16	31.4	2	14	27.5
Office of Manufacturing Management Research	Feb-91	172	15	20.8	30	27	90.0	41	56.9	12	29	40.3
	Totals:	123	23	18.7	46	37	80.4	57	46.3	14	43	35.0

Footnote #1: 3 letters were initially received regarding their regrets in declining to respond. 2 additional declines were recieved during follow-up calls.
Footnote #2: Individual responses refers to total number of surveys returned. Multiple responses refer to more than one response from a company.

Table 2

Respondent Summary by Position

Position Name	Frequency	(%)
Top Management	11	(26%)
Middle Management	27	(63%)
Staff	1	(2%)
N/A	4	(9%)
Total	43	(100%)

Table 3 shows the distribution of company product types according to Standard Industrial Classification. The industries of the respondents to an in-plant study in 1987 (see footnote one) are listed in Table 3 for comparison. They are very similar in representation of codes 34-37, but the 1991 study includes many more firms outside this range, as well.

Finally, the cross-section of respondents was characterized according to the Fortune 500. Twenty-four (56%) of the 43 companies were found on the list. In fact, all 24 were in the top 250. Of those, 19 were in the top 33% and 16 were in the top 20%. Of the companies who did not appear in the 500, their sales were defined by billions down to tens of millions of dollars. Therefore, the respondents represented a broad cross-section of American industry. About half of the respondents did not appear in the Fortune 500 while the other half solidly represented the largest companies in the United States.

Using a Dun and Bradstreet analysis of the non-respondents, we found average sales of non-responding companies was smaller than responding firms ($t = 7.12$, $p < .01$). (Variance of sales was also not the same, so this test was restricted.) Average sales of the 43 responding firms was $16.7 billion. Average sales of the 37 non-responding firms for which data were available was $2.7 billion. Respondents represented firms larger than those that did not respond.

3.0 Results

The results reported here are for just the preliminary survey and, for the most part, descriptive. There are no correlation analyses (e.g., association between one design practice and other answers in the survey or performance of that business unit or firm). These analyses are being carried out separately and subsequent to this report, but will be available at a later date.

The results were enhanced in their usefulness by the fact that many of these questions have been asked before in similar in-plant survey carried out in 1987. (Again, see footnote 1.) Although most of the firms participating in the two surveys were different, they represent essentially they same industries. So, among other things, an approximate four-year longitudinal comparison of domestic product development and design practice documentation was obtained.

Table 3
Distribution of Firms by SIC Code:
1991 and 1987

	1991			1987		
	2 Digits SIC Code	Frequency (%)		2 Digits SIC Code	Frequency (%)	
Furniture & Fixtures	25	4	(9.3%)	--	--	--
Rubber & Miscellaneous Plastics Products	28	1	(2.3%)	--	--	--
Fabricated Metal Products	34	2	(4.7%)	34	6	(15%)
Machinery	35	13	(30.2%)	35	16	(41%)
Electrical & Electric Machinery, Equipment, & Supplies	36	8	(18.6%)	36	5	(13%)
Transportation Equipment	37	7	(16.2%)	37	10	(26%)
Measuring, Analyzing and Controlling Instruments	38	3	(6.9%)	--	--	--
Other	N/A	5	(11.6%)	Other	2	(5%)
Totals		43	(99.8%)		39	(100%)

3.1 Changing Nature of the Product Development Process

Much of the attention in the preliminary mailed survey was focused on indirect and direct comparisons needed to document the nature of the changes that firms are experiencing in their design and product development processes. For example, the very first substantive question on the survey asks respondents whether or not their firm has a program to upgrade the product development process. Of the 43 people responding to this question, the vast majority, 42 (98%) said "yes." Five (12%) said the program included quality, time to market, suppliers and, seven (16.3%) included plant modernization. Thirteen (30%) said the program included all these four areas plus a special initiative, e.g., elimination of waste in all things, including the process development process. What is more, most (33 or 77%) of these same respondents said their firm had a multi-focus (three or more foci) program change effort for product development. One hypothesis that could be tested in subsequent analysis is that the more focussed these efforts, the more successful they are.

The context of this change effort varied considerably by business unit and product line as well as firm and industry. For example, the current and projected life-cycle of products averaged 13.4 and 10.4 years, respectively. But these distributions were skewed. The median product life-cycle for 43 respondents was 8 years, and the median, projected life-cycle was 4.5 years for those 33 people reporting the latter statistic. As would be expected, product life-cycles are getting shorter, according to this responding sample of firm representatives. A hypothesis to be tested by subsequent analysis is that the urgency of programs (e.g., emphasis on shortening time-to-market times) is likely to be significantly and inversely associated with the percentage reduction in product life-cycle projection and launch time as compared to current life cycle and launch times.

Six of the questions included on the preliminary survey were asked in a similar study in 1987 (see footnote one). Only those companies participated in both surveys, but product groups are identical. Both were national samples. The comparisons in responses of product manufacturing companies in SICs 34-37 for the previous (1987) in-plant interviews and this preliminary mail survey (1991) are presented in Table 4 below.

The first question covers the concept development effort[3] for current products as a proportion of total time spent on the effort. In 1991, the mean reported concept development effort was 25.4% (median = 25%) and in 1987 for a similar sample of product plants, the mean proportion of effort was 28.1% (median = 30%), or slightly more. The target for the 1991 sample was reported to be 26.1% (median = 30%) but only 29 people (vs. 38 in 1987) actually responded to the "goal" question. There seems to be little shift in these percentages during the last four years.[4]

The second question asks whether or not people involved in design have been trained in DFA (Design for Assembly) or DFM (Design for Manufacture), and if anyone had, who was trained for what. There is a dramatic shift in the answers comparing 1987 and 1991 for this question. In 1991, 24 or 56% of survey respondents said at least one person had been trained. In 1987, only 6 or 18.2% of plant respondents said at least one person had been trained in DFA or DFM. This is the most substantial change in any of the six questions asked that are summarized in Table 4. It appears clear that firms in U.S. product industries have made a dramatic shift in their investment in training and development for new product introduction during the last four years.

The third question asked respondents to comment on whether or not a manufacturing representative signs off on design reviews, and if yes, at what stage of the process. Here the

---

[3]See John E. Ettlie, "Concept Development Effort in Manufacturing," presented at the Symposium on Design for Manufacturing, Pennsylvania State University, University Park, PA, August 22-25, 1990, revised February, 1991.

Note that in George Stalk's book (G. Stalk and T. M. Hout, Competing Against Time, New York, The Free Press, 1990, p. 118), even though Japan took less time, both the Japanese and Western Company making mechanical transmissions spent 8% of the total new products development time on concept development (3.1 and 1.5 mo., respectively).

[4]The test for difference in means found that $t = 1.58$ (df = 62, n.s.) which is not statistically significant. Therefore, we concluded that these two populations are the same for average concept development effort.

Table 4
Comparison of 1987 and 1991 Design Practices

Question		1991	(goal)	1987
1. Percentage of total product development time devoted to concept development.@ (goal?)	mean	= 25.4%	26.1%	28.1%
	median	= 25%	30.0%	30.0%
	s.d.	= 16.9%	14.8%	17.7%
	n	= 39	29	25 (plants)
2. We have people who are trained in DFA or DFM,# (IF YES) Who was trained for what?	Yes	= 24 (55.8%)		6 (18.2%)
	No	= 9 (20.9%)		25 (75.8%)
	In Process	= 10 (23.3%)		2 (6.1%)
		43		33
3. A manufacturing representative is required to sign-off on design reviews for new products.	Yes	= 34 (79.1%)		24 (70.6%)
	No	= 5 (11.6%)		9 (26.5%)
	In Process	= 4 (9.3%)		1 (2.9%)
(IF YES) When are design reviews signed off?		43		34
a. Concept Design				
b. Preliminary Design				
c. Prototype				
d. Production Release				
4. We have developed and implemented new structures in order to coordinate design and manufacturing. (IF YES, what are these structures?)	Yes	= 28 (65.1%)		17 (45.9%)
	No	= 5 (11.6%)		18 (48.6%)
	In Process	= 10 (23.3%)		2 (5.4%)
		43		37
5. Job rotation between design and manufacturing engineering is practiced in this firm.	Yes	= 8 (18.6%)		3 (8.8%)
	No	= 26 (60.5%)		30 (88.2%)
	In Process	= 9 (20.9%)		1 (2.9%)
		43		34
6. Personnel from design engineering are sometimes moved to manufacturing engineering or vice-versa.	Yes	= 22 (52%)		13 (36.1%)
	No	= 13 (31.0%)		21 (58.3%)
	In Process	= 7 (16.7%)		22 (5.6%)
		42		36

Response Distributions: columns 1991, (goal), 1987.

@These questions were asked slightly differently in 1987 and 1991; In 1991 the question read: "What percentage of your last new product's development time was devoted to concept development?____ goal? ____." In 1987, the interviewer read the following question: "What percentage of a project's duration is devoted to concept development? _____%." The remainder of the questions were exactly the same.

#Response format for questions 2-6: coded as "yes" = 1, "No" = 2, and "In-process" = 3.

changes are not dramatic. In 1991, 34 or 79% of managers said manufacturing signs off at some point in the product development process, whereas, in 1987, 24 or 70.6% agreed. Manufacturing sign-off was, and appears to continue to be an important mechanism for coordinating design and product development.

When manufacturing signs off is also an interesting question. Assuming four milestones in the product development process (Concept Decision, Preliminary Design, Prototype, Production Release), the respondent was asked to choose when the design reviews are signed off, 2 people (5%) of the 39 responded that the sign off occured at Concept Decision. Six (15.4%) of people chose Preliminary Design, while 4 (10.3%) chose Production Release. The one person who chose Prototype wrote that it was planned to move sign off up to Concept Decision and/or Preliminary Design, instead.

It is very interesting to note that the largest category of response, unprompted to circle more than one option, was that manufacturing sign off was required <u>at all four milestones</u>. This method received twice the number of votes over any other, 12 (31%). The remaining respondents who have manufacturing sign offs said it occured during more than one phase, but almost never as early as Concept Decision.

Perhaps one of most interesting aspects of accomplishing new goals for product development program change is the introduction of <u>new structures</u>. Earlier (see Footnote one) we found that the use of teams, in particular, was significantly related to return on investment of new projects for modernization. Not surprisingly, there has been substantial movement on the distribution of answers to the fourth question (Table 4) concerning the use of new structures in the product industries. In 1991, 28 respondents (<u>65.1%</u>) said they had developed and implemented new structures for coordination of design and manufacturing. In 1987, only 17 or <u>45.9%</u> of respondents agreed. This represents a rather visible shift to using new structures for accomplishing program change.

When plants, business units and firms restructure, they make a commitment to change that represents more than just lip-service. These changes vary broadly from new position to ad-hoc steering committees to new teams. The distribution of new structures in 1991 versus 1987 is given in Table 5.

Clearly, the use of teams was and is important in restructuring for product development changes. In 1991, 15(50%) of the survey questionnaire respondents said this is the mechanism they are using to change structure. In 1987, 7(41%) agreed. It was the top choice in both years. Concurrent engineering teams, planning teams, crossfunctional groups and co-located functions were mentioned frequently. Firms are also formalizing the process and introduction discipline into the design process (8 or 26% of the responses in 1991). This includes adopting new integrating CIM systems.

One hypothesis that could be tested later with inferential statistics is that the type of restructuring used to implement new product development philosophies varies by firm, industry and strategy. What is more, it might well have an impact on, or be related to other practices and outcomes of change efforts.

We did ask respondents (Question 9) if they used to terms "simultaneous engineering" or "concurrent engineering" or other terms to describe their design approaches in the 1991 mailed survey. The majority said "simultaneous" (16 or 37%) or "concurrent" (13 or 30%) engineering was the team they used. Some firms (2) use "integrated" engineering, others (3) use both terms.

A question very much related to these issues appeared on the survey (No. 11): "What members of the organization outside the design and manufacturing engineering function are involved in this design approach?" The first, and we assume the most important of the functions reported were coded into categories and compared to answers to a very similar question in 1987 (see Footnote one). These data appear in Table 6 below.

Marketing and related functions (e.g., sales, product planning) were, and remain, among the most important "outside" functions for design and product development as would be expected. This function scored first in popularity in 1987 (9 or 36% of the time) and first (13 or 30% of the time) in 1991. Second in 1991 was the quality function which was mentioned in 9 or 21% of the

Table 5
Distribution of Structural Adaptations in Product Development: 1991 and 1987

Category		Frequencies (%) 1991	1987[@]
Teams		15 (50%)	7 (41%)
Formalized or Disciplined Process		8 (26%)	2 (12%)
New Position or Roles		9 (13%)	4 (24%)
Business Unit Reorganization		1 (5%)	2 (12%)
Other		2 (6%)	2 (12%)
	Totals	30(98%)	17(101%)

[@]Source: J. Ettlie and H. Stoll, Managing the Design-Manufacturing Process, New York, NY: McGraw-Hill, 1990, p. 61.

Table 6
Cross-functional Team Members Representing Areas Outside Design and Manufacturing: 1991 and 1987.

Category	Frequencies (%) 1991	1987
Marketing (Sales@)	13 (30.2%)	9 (36%)
Quality, Reliability	9 (21%)	6 (24%)
Production (Control)	3 (7.0%)	-
Purchasing (Materials, Suppliers)	4 (9.3%)	-
Engineering (Systems, Human Factors)	3 (6.9%)	-
Business Unit or Corp.	2 (4.7%)	4 (16%)
Other (Finance, R & D, Customers, etc.)	7 (18.6%)	4 (16%)
Service	1 (2.3%)	2 (8%)
Totals:	26 (99.9%)	25(100%)

*Does not include product planning or product engineering which is included under "other" here.

cases that responded. The quality or related functions (e.g. test) also ranked second in 1987. These trends seem unaltered.

There seems to be a fair amount of consistency in the types of functions represented on these crossfunctional teams for design and product development. However, answers in 1991 show considerably more variance--not only in functions represented but in answers to questions discussed later that have an open-ended format. This and other results suggest that more and more firms are developing their own unique "mosaic" strategy for implementing new product development philosophies--at least for the time being.

Job rotation is a technique for development of human resources often used at the entry level, regardless of culture. It is not surprising that this technique is used sparingly to help coordinate design and manufacturing during product development because it's usually the seasoned professional and manager who is involved. In 1991, 8 respondents (18.6%) reported using this mechanism for coordination. In 1987, the incidence of reported use was even less, with 3 or 8.8% of plant reporting its use. Although the incidence of use has doubled in four years, it's still rather rare for companies to report rotating engineers between design and manufacturing. One can speculate that alternative mechanisms, such as permanent mobility (discussed below) or temporary, multiple job assignment that are used more often. These two alternatives are sometimes reported on surveys and in cases.

Movement of personnel across functions is investigated in the last question in Table 4--specifically, the movement of engineers from design to manufacturing or vice-versa for the purpose of coordination in product development. In 1991, 22 (of 42) or 52% of survey respondents reported that they were using this mechanism for coordination. The incidence of using this mechanism for coordination was somewhat less, as would be expected, in 1987, with 13 or 36.1% of managers reporting its use. This approach is obviously used far more often in 1991 than job rotation (18.6%), but not as often as training (55.8%), manufacturing signoff (79.1%), or other new structures (65.1%), in 1991.

3.2 Benchmarking

Considerable amount of interest in product development has been generated by successful firms in the 1980's by their use of benchmarking. Xerox, for example[5] has been widely celebrated, along with many other successful firms, for their use of measuring and comparing practices on various dimensions of world-class manufacturing product and process practices to help improve performance and quality. Xerox benchmarked for cost, methods and service in the 1980's.

We assumed that benchmarking would be an integral part of changing the philosophy of product development in other domestic manufacturing firms. When 98% of our preliminary survey respondents said they have a program to upgrade product development, we also assumed that most or a majority of these same responding firms would also be benchmarking. This was not the case. In response to the question, (no. 12 on the survey, see Appendix); "Do you BENCHMARK (Make visits to other firms and gauge their practices because of their known good reputation) in Design Approaches?" we were somewhat surprised to find that 24 of the 43 or 56% of the respondents said "yes". That is, only about half of these firms benchmark in product development[6], even though nearly all are in the process of changing the way they do product development.

As would be expected, based on these results, about half of the respondents did name a benchmark firm for product development in Question 13 (Appendix) of the survey in 1991. Nine (39%) of the first mentioned benchmark firms were Japanese. It may well be (and telephone conversations with some respondents indicates this is the case) that many of these firms have just embarked on their new product development program. Further, these firms may very well be

---

[5] See, for example, Gary Jacobson and John Hillkirk, Xerox: American Samurai, New York, NY: MacMillan Publishing Co., 1986.

[6] We verified that those firms that said they do benchmark could name a benchmark firm in Question 13 (Appendix). This was true in all cases.

benchmarking others on issues such as quality and productivity, which would not necessarily show up in the answers to Question 12 on benchmarking for product development.

Other benchmarking related questions were asked, based on previous reports of product development practices and problems. For example, we asked what percentage of engineers were degreed, given that managers often report that this is a problem in product development and coordination when new design practices are being adopted. The results are reported in Table 7 below. As would be expected, based on past practice, more degreed design engineers reside in these firms than degreed manufacturing engineers, on average, but the distribution of baccalaureate engineers is somewhat skewed for both design and manufacturing. The average percentage of degree design engineers was 74.7% (median = 90%) for 42 reports, while the average percentage of degreed manufacturing engineers was 61.0% (median = 60%) for 40 reporting respondents. A hypothesis to investigate with subsequent analysis would be to see of the percentage of degreed engineers is associated with other design practices and outcomes.

The ratio of design to manufacturing engineers is something we have investigated earlier, and is often implicated in problems of product development coordination. Manufacturing engineers often complain that they must spend too much time extinguishing fires and not enough time planning. The mean ratio of design to manufacturing engineers in the 1991 survey was 4.69 to 1 (median = 3 to 1) for 39 reporting cases which suggests some skewing. This average ratio was 2.88 to 1 in 1987 with 27 reporting cases. In the 1987 data (see Footnote one) we also found that a ratio of 2:1 tended to optimize design-manufacturing integration, so the average firm in the 1991 survey may be somewhat different than in 1987. This hypothesis, and others concerning this ratio could be evaluated in subsequent analysis. Six firms reported a 2:1 ratio in 1991. Are these the "best practice" firms? Or does it vary by industry? These are all interesting questions, yet to be answered.

Since many firms seem to be preoccupied with getting products to market faster (rather than timing, per se, in domestic manufacturing), we asked (in Question 4, see Appendix) how long it

Table 7
Percentage of Degreed Design and Manufacturing Engineers

Percentage Degreed Design Engineers

VALUE	FREQUENCY	PERCENT	VALID PERCENT
0	1	2.3	2.4
1	1	2.3	2.4
15	1	2.3	2.4
25	1	2.3	2.4
30	2	4.7	4.8
33	1	2.3	2.4
35	1	2.3	2.4
50	2	4.7	4.8
70	3	7.0	7.1
75	1	2.3	2.4
80	4	9.3	9.5
85	2	4.7	4.8
90	6	14.0	14.3
95	7	16.3	16.7
99	9	20.9	21.4
-1	1	2.3	MISSING
TOTAL	44	100.0	100.0

MEAN 76.000 MEDIAN 90.000 MODE 99.000
STD DEV 28.357

VALID CASES 41 MISSING CASES 3

Percentage Degreed Manufacturing Engineers

VALUE	FREQUENCY	PERCENT	VALID PERCENT
0	2	4.7	5.0
10	2	4.7	5.0
20	2	4.7	5.0
29	1	2.3	2.5
30	2	4.7	5.0
33	1	2.3	2.5
40	2	4.7	5.0
50	4	9.3	10.0
60	5	11.6	12.5
65	2	4.7	5.0
70	1	2.3	2.5
80	2	4.7	5.0
90	6	14.0	15.0
95	3	7.0	7.5
99	5	11.6	12.5
-1	3	7.0	MISSING
TOTAL	44	100.0	100.0

MEAN 57.579 MEDIAN 60.000 MODE 50.000
STD DEV 31.323

VALID CASES 38 MISSING CASES 6

took to introduce the last product and what the current goal was. In 1991, the average lead time (concept to market) was 3.11 years (median = 3 years, standard deviation = 1.54 years) for 41 reporting managers. The goal average lead time was 1.79 years (median = 1.5 years, standard deviation = 1.08 years, 37 respondents). These numbers are somewhat shorter and more aggressive than those reported for the automobile industry, but an array of industries are represented. Since most firms report that they want to reduce lead time by 50%, it is not surprising that the actual average (3.1 years) and average goal (1.8 years) for this sample approximate that target often mentioned at 40% reduction in lead time. These comparisons obviously depend upon your starting point and your industry benchmark. Current lead-time could be used as a performance measure to evaluate design practices and product development process factors in this study, and one hypothesis that could be tested is the oft tauted idea that concurrent engineering shortens lead-time. We suspect that when firms try teams for the first time, it actually takes longer to introduce new products--even if their performance is higher because it takes time to learn the team process in the typical domestic firm. It would be necessary to control for product life-cycle to test this hypothesis.

There were two more questions on the survey in 1991 that tend to summarize many of the issues surrounding benchmarking for product development. The first question (no. 10 on the questionnaire) asks what is the purpose (goal?) of the design approach being used in the firm, and follows the question asking whether or not the terms concurrent or simultaneous engineering are used there. The results of grouping these responses by goal category are presented in Table 8 below. Priority was given to the "most ultimate" outcome mentioned.

The most frequently mentioned first goal was the attainment of multiple objectives--especially the maintenance of or reduction of cost and improvement of quality while being able to get to market quicker with new products. An example was "Reduce time-to-market; improve first time product quality, minimize product evolutionary changes." A total of 16 (43.2%) of people responding to this question emphasized the attainment of multiple, simultaneous goals for product

Table 8
Purpose of Design Approach in the Firm

Purpose		Frequency (%)
1. Multiple, Simultaneous Purpose (e.g., time, cost, quality)		16 (43.2%)
2. Integrated Design Approach (CE and beyond)		14 (38%)
3. Cycle Time Reduction		4 (9.3%)
4. Other		3 (8.1%)
	Totals	37 (100%)

design and development programs. <u>This is important, because speed or cycle-time reduction alone was only mentioned by 4 (9.3%) of respondents</u>. Cycle-time reduction <u>alone</u> was not the dominant product development objective for this sample.

The second most frequently mentioned first purpose was the achievement of an <u>integrated design approach</u>. This was reported by 14 (38%) of those responding to this question. This included not only getting design and manufacturing involved but other functions as well and echoes the responses to structure questions covered earlier (Tables 5, 6).

Finally, we asked survey questionnaire respondents in 1991 what measures they used to evaluate the success of design-manufacturing integration, as we also did in 1987. The results of the comparison of first answers given to this question four years apart are presented in Table 9 below.

This data represents a rather substantial shift in practices in domestic manufacturing. In 1987, the most common first answer to this evaluation question was that ultimate outcomes were used like cost and productivity. In 1991, <u>in-process indicators</u> have taken over as the primary substantive response to this question. Fifteen or 35% of all responses, including missing (37%) mentioned in process measures. The actual type of in-process measures go beyond just the reduction of iterations in design and design changes required just before production or after release to production of a new product. They include such things as the <u>criteria for exiting a gate</u> in the review process for designs, <u>team status reports</u>, and the like. <u>This is one of the most interesting developments detected by this preliminary survey and worth following up in subsequent analysis and survey activity</u>. One <u>hypotheses</u> is that firms that are using in-process measures are more successful in their design and product development philosophical shift than firms that do not rely on these in-process measures.

One other result that is noteworthy in Table 8: The frequency of missing data (otherwise not mentioned in tables earlier) is quite high at 19 (43%). Are firms beginning to discover the usefulness of keeping in-process measures to themselves? This is also worth exploring in follow-up activity.

Table 9
Measures of Successful Design-Manufacturing Integration: 1991 versus 1987

	Frequencies (%)	
Category	1991	1987
1. In-Process Indicators (e.g., design change orders, design interations)	15 (35%)	5 (13%)
2. Ultimate Outcomes (e.g., cost, productivity)	6 (14%)	20 (51%)
3. None (We don't evaluate this)	6 (14%)	10 (26%)
4. Missing	16 (37%)	4 (10%)

3.3 Financial Planning

One of the assumptions of this research project was that firms do not do detailed costing studies of new products until they go into production. However, we also assumed that as part of the adoption of new philosophies of product development in domestic manufacturing firms, these practices might be undergoing change--that is, perhaps some organizations were beginning to drive cost estimating upstream in the new product life-cycle, perhaps even to the point of doing some cost estimating during the design stage. We attempted to find out if this were the case by including three questions on the preliminary mailed survey to this end (questions 16, 17, and 18, see Appendix).

The first question we asked was whether or not financial planning during product design includes projections of future costs and revenues. We were amazed to find that 38 (88.4%) of respondents responded "yes". Four respondents said "no" and one said they do cost, not revenue planning. It seems quite likely that respondents confused this question with a query about capital budgeting and proposal preparation for new product development--which is more a forecast using very crude estimates in a gross fashion. It does not include detailed estimates of the impact of new products on production process and costs, nor does it usually include firm, fixed-price cost estimates from supplier of equipment or materials and parts.[7]

The answers to the second question were even more unexpected: "Do you estimate the production cost impact of alternative product designs?" A whopping 41 or 95% of our respondents said "yes". Our professional experience suggests that detailed cost impact estimates are exceedingly rare in domestic manufacturing product development practice. Therefore, we are left with the puzzle of what these respondents are suggesting by their answers.

---

[7] A recent survey of new accounting practices found only 4 percent of firms actually using Activity-Based Accounting. We expected similar result here. (See F. B. Green and Felix E. Amenkhienan, "Production Accounting Practices in Select Manufacturing Firms: A Survey," Radford University, Radford, VA, presented at the Operations Management Association Meeting, Dallas, TX, April 26, 1991).

The third question asks at what stage of the product life-cycle financial controls are used. A total of 20 or 47.6% said during product concept formulation. Again, these results are very unusual based on our experience, and clarification of this section of the study will be required with further pilot testing. We are going to completely overhaul this segment of the survey for the next phase of the project.

3.4 Problems and Prospects for Changing the Product Development Process

The last two open-ended questions on the mail survey concerned the overall issues of managing the design and product development process in manufacturing. Question 14 asked respondents what they thought the key determinants of success for the design process were. Answers were grouped by first response in categories and summarized in Table 10 below.

Focus on the customer and quality received the highest number of votes with 14 (36%) of respondents indicating their importance in good design. Next was integration of functions, which echoes earlier answers, with 10 or 26% or respondents indicating crossfunctional teamwork as important. Simplification (6 or 15%), and design tools (4 or 10%) round out the answers other than misc. Again, note that speed to market, per se, did not emerge as very important in the answers to this question. Either it has not impacted these firms, has become integrated as a trade-off, or is not thought of in the context of success factors (see below).

The final open-ended question (No. 15) asked respondents to summarize the barriers to "achieving high quality, design, quickly." The answers listed first were grouped and summarized in Table 11. Interestingly, the barriers reported most often are not a mirror image of the answers reported in Question 14. The number of barrier reported to achieving high quality designs, quickly was (absence of) communication and goal clarity, with 14 (36%) of the mentions tallied. Next was culture and its barriers with 8 (21%), of the respondents reporting this first as a barrier. To round out the answers, lack of time (6 or 15%) and customer knowledge (6 or 15%) were also noted. Here time (time compression) stress begins to show through in the survey, unlike in the other parts

Table 10
Determinanats of Success of Good Design

Category		Frequency (%)
1. Know Customer; Quality		14 (36%)
2. Integration of Functions		10 (26%)
3. Simplify Design		6 (15%)
4. Design Tools (e.g., DFM)		4 (10%)
5. Other (e. g., creativity)		5 (13%)
	Totals	39 (100%)

Table 11
Barriers to Achieving High Quality Designs, Quickly

Category		Frequency (%)
1. Communication & Goal Clarity		14 (36%)
2. Culture (e.g., functional barriers)		8 (21%)
3. Lack of Knowledge of Customer		6 (15%)
4. Lack of Time		6 (15%)
5. Other (e.g., no CAE, FDA)		5 (13%)
	Totals	39 (100%)

of the questionnaire. It appears to be considered a barrier by American Companies, not a success factor. This may be important.

Again, the variety of answers and richness of data, when all the factors listed were taken into account, indicates that things are changing rapidly in domestic product development. For example, the NIH or "Not Invented Here" factor is often mentioned as a chronic and persistent problem in achieving integration goals. Lack of management vision and experience is often cited at some point in each respondent list, as well. Whether or not designs should be "made" rather than "bought" is an issue on some people's minds--but all of these take a back seat to customer and quality concerns. All of this assumes that what people list first is their priority concern. (Table 10, 11).

4.0 Summary and Conclusions

We surveyed 43 manufacturing companies and divisions to determine the state-of-the-art of product development philosophies, strategies and practices, in U.S. based manufacturing. Respondents were usually middle managers (63%) or top managers (general manager or above, 25%). Although 31 product types were represented, most were in SIC 34-37, which is fabricated metal products, machinery, electrical equipment and transportation equipment (e.g., aero space, automobiles). Twenty-four of responding firms were in the Fortune 250 and the sample averaged $16 billion in sales.

Results were quite unexpected on several issues. Although all but one of the responding firms said they had a program to upgrade the way they develop products, only a slim majority of these companies (24 or 56%) bench mark on product development processes. What is more, manufacturing almost never gets formally involved in the concept development stage formally, yet this may be the most important part of the product development effort. Cycle time reduction was not only conspicuous by its absence as a driver in product development strategies, it was often mentioned as a barrier rather than a strategic opportunity or target. Merely including time as a trade-off seems inconsistent with the attention this variable is receiving in theory and practice of design today.

In comparing survey results from 1991 with similar (but not identical) firms from another study in 1987, there is good news and bad news. While companies are using more training and development (e.g., design-for-manufacturing) to enhance their design practices, there still appears to be resistance to adopting job rotation among functions. Marketing is still the number one choice function outside engineering for involvement in efforts to integrate design, and quality is second, as in 1987. Firms continue to increase their use of manufacturing sign-off and new structures (e.g., teams) to implement their new product development philosophies.

There continues to be a gap between degreed design versus manufacturing engineers. The average percentage of degreed design engineers in the sample was 74.7% (median=90%), while the average percentage of degreed manufacturing engineers was 61.0% (median = 60%). The average ratio of design to manufacturing engineers was 4.69 to one, whereas this ratio was 2.88 to one in the 1987 survey. That is, there has been no improvement in these ratios.

Although firms are attempting to accomplish multiple purposes with their new design approaches (e.g., cost, quality, timing) only a slightly greater number are using in-process measures (e.g., reduction in design change requests) to monitor their progress towards those goals. In 1987, 13% of the sample used in-process measures, and in 1991, 35% used these same or newer measures (e.g., milepost passage reports).

Not surprisingly, respondents felt that the most important determinant of success in product development was to know your customer and integrate functions. What is more, the absence of good communication and goal clarity were the most frequently mentioned barriers to acheiving high quality designs, quickly.

MANAGING DESIGN SYSTEMS IN MANUFACTURING

John E. Ettlie, Ph.D.
Director
Manufacturing Management Research
School of Business Administration
The University of Michigan
Ann Arbor, Michigan 48109-1234
(313)936-2835

October 1990

PROJECT DESCRIPTION

The purpose of this project is to investigate integrated approaches to design in manufacturing. It is being done in collaboration with Professors Dan Shunk, Richard Beltramini, and Peter Hom at Arizona State University and Professor Germain Boer at Vanderbilt University.

Through the collaboration of Engineering, Business School, and Industrial partners, we expect to determine the subtle and fine points of how to satisfy the often conflicting goals of high quality and rapid product development. Conventional wisdom tells us that this is not possible, or is carried out with extreme difficulty. In the next decade, this situation is likely to change and our research aims at determining how this transition occurs across a large number of different types of firms in a variety of industry settings.

The project is being funded by the National Science Foundation under Grant No. DDM-9007043 to The University of Michigan. John E. Ettlie is the principal investigator.

CONFIDENTIALITY

All questionnaires and interviews on this project are done in confidence. We do not associate any data, or opinions with names of people, plants, companies or products. If you ever have a question about this research, please call John E. Ettlie at the number above.

FEEDBACK

Summaries of results are available to those participants requesting them. Write or call John E. Ettlie.

MANAGING DESIGN SYSTEMS IN MANUFACTURING

Preliminary Questionnaire

Name ____
Address ____
____
____
____ (attach Business card here)

(Attach Business Card if you have one)

Phone ( ) ____

1. Does your firm or business unit currently have a program to upgrade the product development process?

   Yes No (skip to question 3)

2. What areas does this program cover: (circle all that apply)

   a) Quality
   b) time to market
   c) Suppliers
   d) Plant modernization
   e) other____
   (please name)

3. What is the current life cycle of your main product(s)?_______(yrs.) Projected?_______(yrs.)

4. How long did it take (concept to market) to introduce your last new product?_______(yrs.) Goal?_______(yrs.)

5. What percentage of your last new product's development time duration was devoted to concept development?________% Goal?________%

6. What measures do you use to evaluate the success of design-manufacturing integration for new development efforts? (If none (skip to question 7)

Integration measures:____

7. What is the ratio of your design engineers to your manufacturing engineers?_______:_______.

8. What percentage of your design engineers have a bachelor's degree in engineering?_______%
   What percentage of your manufacturing engineers have a bachelor's degree?________%

9. Do you use any of the following terms to describe your design approach(es)? (Circle the one that most applies) (If NONE, skip to question 11).

   a. Simultaneous engineering
   b. Concurrent engineering
   c. Other_______________.
   (Please Name)

10. What is the stated purpose of this design approach:

    ____

    ____

11. What members of the organization outside the design and manufacturing engineering function are involved in this design approach? (Name function in order of importance)

    a. ________________ (most important other function)
    b. ________________
    c. ________________
    d. ________________ (least important, but involved)

12. Do you BENCHMARK (Make visits to other firms and gauge their practices because of their known good reputation) in Design Approaches?

    Yes No (skip to question 14)

13. Which organizations do you think are good benchmarks in design approach?

    ____

    ____

    ____

14. What are the factors that you think are the key determinants of success of a good design approach in manufacturing?

    a. ________________
    b. ________________
    c. ________________
    d. ________________

15. What are the most important barriers to achieving high quality designs, quickly?

    a. ________________
    b. ________________
    c. ________________
    d. ________________

16. Does financial planning in your product design process include projections of future costs and revenues the product might produce?

Yes No

17. Do you estimate the production cost impact of alternative product designs?

Yes No

18. At what stage in the life of a product do your company financial controls come into play?

a. Product concept formulation
b. Detail product design
c. Product prototype
d. Manufacturing process design
e. Actual production of the product

	YES	NO	IN PROCESS
19. We have people who are trained in DFA or DFM.................	1	2	3

(IF YES) Who was trained for what?

____

____

____

	YES	NO	IN PROCESS
20. A Manufacturing representative is required to sign-off on design reviews for new products	1	2	3

(IF YES) When are design reviews signed off?

a. Concept decision
b. Preliminary design
c. Prototype
d. Production release

	YES	NO	IN PROCESS
21. We have developed and implemented new structures in order to coordinate design and manufacturing..................	1	2	3

(IF YES) What are these structures?

____

	YES	NO	IN PROCESS
22. Job rotation between design and manufacturing engineering is practices in this firm..................................	1	2	3

23. Personnel from design engineering are sometimes

moved to manufacturing engineering or vice-versa............... 1 2 3

24. Are you the best person(s) to contact for follow-up on this project? Yes No.
(If No, please provide person's name and number________________________________)

Please return this questionnaire in the attached envelope.

THANK YOU!