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Abstract: This report examines the duration and efficiency of new product development programs. The objective is to investigate engineering trends, and to identify program characteristics that shorten the development cycle and/or reduce the resources required to develop new products. We chose the automobile industry as the target industry due to the availability of information, but our findings can be applied to other products and industries.

INVESTIGATION OF THE DURATION AND EFFICIENCY OF NEW PRODUCT DEVELOPMENT PROGRAMS

D. Cross

EMP - P8813

EAS 506 SPECIAL PROJECTS

ENGINEERING MANAGEMENT SYNTHESIS

TERM PROJECT

INVESTIGATION OF THE DURATION AND EFFICIENCY OF NEW PRODUCT DEVELOPMENT PROGRAMS

SUBMITTED TO

DR. DUNDAR F. KOCAOGLU

BY

DARRELL K. CROSS

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EXECUTIVE SUMMARY

This report examines the duration and efficiency of new product development programs. The automobile industry receives the greatest attention, but the findings apply to other products and industries.

Three information sources were employed: a literature search, personal correspondence with various experts, and the experience of Hyster Company -- where this author is employed.

A consistent picture emerges of efficient product development programs. Their distinguishing characteristics include: a project management style of organization structure, overlapping of project stages with activities proceeding in parallel, supplier involvement, and application of new engineering technology. Evidence suggests that reductions in duration and labor of almost 50% are possible with this product development approach.

I. INTRODUCTION

This report covers an investigation on the duration and efficiency of new product development programs. The automobile industry receives the greatest attention because of the availability of information, and the relative economic importance of this industry. The general findings apply to other products and industries, however.

The objective was to investigate engineering trends, with the hope of identifying program characteristics that shorten the development cycle and/or reduce the resources required to develop new products. Of particular interest were reports (largely unsubstantiated) that product development cycles were shorter in Japan than in the United States or Western Europe.

Product development efficiency is a critical management issue. The current business environment is typified by intense global competition, rapid technological change, and high consumer expectations for product quality and value (1). Corporate survival often hinges on the ability to develop new products in quick response to changing market conditions.

This investigation spanned summer and fall terms -- June 20, to December 9, 1988 -- because of the difficulty in obtaining support information. The initial goal was to uncover the information by conducting a comprehensive literature search of books, technical journals, and business peridicals. Upon reviewing the published material, it became apparent that this information lacked depth, and was of limited value. Product development work is conducted in the private sector. Results are typically confidential for competitve reasons.

In September of 1988, Dr. Kocauglu suggested an alternate source of information. He suggested I correspond with various scholars and researchers with first hand experience in the private sector. Results of that correspondence greatly exceeded expectations. Responses were received from a professor and an engineering director in Japan, from a researcher at the National Science Foundation, and from college professors and an auto executive in the United States. Dr. Kim Clark from the Harvard Business School was particularly helpful. He sent four draft working papers as part of an ongoing study of product development in the world automobile industry. Copies of the draft reports and all other correspondence are included in the Appendix behind tabs 1-5.

In general, results of the correspondence were at least as informative as the literature search. Therefore, they receive equal emphasis in this report.

This author is currently employed as a product planning manager for Hyster Company, where I am involved with the planning and development of new products. This investigation has immediate relevance to my work. Hyster is a multi-national organization that engineers, manufactures, and markets heavy industrial equipment. Products include materials handling machinery, highway compaction equipment, and industrial trailers. Fork lift trucks account for the bulk of annual sales. Hyster has made noteworthy progress in reducing the new product development cycle. That progress is briefly reviewed in one section of this report.

The overall aim of this report is to provide a concise summary and synthesis of the literature search, correspondence, and Hyster experience. From those results, conclusions are reached which form a more complete picture of new product development.

A bibliography of cited material is found at the end of the report. Numbers found in parenthesis designate specific references in the bibliography.

II. LITERATURE SEARCH

New product development activities are generally considered important by management, thus there is a lot of published information on the subject. Upon screening abstracts and card index files, a total of 57 articles and 9 books were reviewed. The results were somewhat disappointing. One reference noted "In spite of the importance of new products, management can find little help from the traditional literature in the formulation of a new product strategy" (2). Most of the material was not comprehensive, and lacked compelling evidence. It often amounted to generic suggestions on how to improve one facet of the development process. Two notable exceptions were a book titled New Products Management by Crawford (3), and the quarterly Journal of Product Innovation Management.

Key literature findings are discussed below. The results are divided into the categories of A) background, B) organization structure, C) engineering, D) manufacturing, E) purchasing, and F) marketing.

A. Background

An article in the Wall Street Journal was typical of many reports comparing Japanese and American product development programs. "The big three auto makers, for instance, all recently formed task teams to cut ponderously bureaucratic development cycles that have swollen to nearly five years. The Japanese, by conparison, can design and build a new car in a little over 3½ years" (4). This was an intriguing observation, but it was unsubstantiated, and did not give solutions other than to reduce bureaucracy.

Excessive bureaucracy can certainly inhibit new product development. An engineering manager for a U.S. auto company reported that the design process took 350 signitures on 350 forms to gain production approval for a single part (5).

Research studies of hundreds of new product introductions showed common traits between successes and failures. Successes were characterized by: understanding of users' needs, attention to marketing and publicity, efficiency of development, effective use of outside technology, and authority of responsible managers. Failures were characterized by: inadequate market analysis, product defects, high costs, bad timing, and strong competitors (6). The differences might also be described as between good and bad management.

The risks associated with new product introductions are high. Various studies show that 20-46% of new products reaching the marketplace, fail (3).

The literature makes frequent reference to computers and office automation as a means to improve productivity and speed up the new product development process (7). Computer-aided design, computer-aided manufacturing, finite element modeling, and various applications of personal computers (such as desk top publishing) are often cited (8)(9).

B. Organization Structure

Functional and stratified organization structures are considered most efficient at managing current business activities (10). The literature clearly emphasizes matrix structures as best suited for managing innovation and new product development (3)(10)(11). "Multifunctional teams are currently the most effective way known to cut through barriers to good design" (5). The matrix structure can be in the form of project management teams, task forces, ad hoc groups, and so forth. The objective is to create an environment of teamwork and collaboration.

Curiously, organizations have been slow to adopt matrix forms. "Many firms are not implementing the team approaches and organizational techniques that this research has once again shown to be effective. Disharmonies between R&D and marketing continue to be surprisingly prevalent, chronic and disruptive to successful new product development. These findings are discouraging, in view of the obvious importance of the topic and an emerging awareness of it"(12).

Matrix structure is not a panacea. Conflict is inherant as a tenuous power balance must exist between functional and matrix managers in order for the structure to operate (13). Conflict exists between project team members as well (14). A controlled level of group conflict is desirable. Research has shown that teams consisting of "too-good friends" are less apt to introduce or challenge new ideas, and the resulting groupthink mentality is less productive (7). The management challenge is to encourage cooperation and development of communication skills, while practicing the art of managing conflict.

Another emerging form of teamwork is interorganizational groups. Close relationships are developing between suppliers, customers, and even competitors in the form of joint ventures (15). Venturing has been described as necessary to experience advanced organizational learning (16).

C. Engineering

Product quality can not be compromised by the drive for short and efficient product development programs. Research on key product success factors concluded that product superiority is the number one factor (6). The definition of superiority includes: unique customer benefits, quality, reduced customer costs, and product innovation. The second factor vital to success was the early activities associated with concept formation. This predevelopment/preliminary work includes: screening of alternatives, market assessment, technical assessment, and financial analysis.

Research of product strategies has shown that over time, and on average, firms have greater success by making incremental market-led product advancements (17). They thereby avoid the higher risks associated with revolutionary offerings. Furthermore, studies have shown 79% of product innovations were market derived (need-pull), and only 21% were from new technological developments (technology-push) (6).

D. Manufacturing

Early manufacturing involvement in the design process is frequently recommended in the literature. This involvement has been described as "design for assembly" (18), "manufacturing by design" (11), and "simultaneous engineering" (8)(19). The basic idea is to design the process as well as product at inception. This avoids costly and time consuming redesign if the product cannot be economically manufactured with available plant and machinery. Related ideas involve accomodation of robotics and automation in product design, and designing for assembly simplicity so that automation is unneccessary.

The practice of early manufacturing involvement in the design process appears to be gaining acceptance. However, a key observation is that the literature stops short of recommending early manufacturing involvment in the manufacturing process. It is assumed that fabrication of tooling and other production preparations begin at (or near) the completion of product design. This aspect of the product development cycle is discussed later in the report.

A final comment on manufacturing relates to the factory of the future. Visions often entail computer controlled, highly automated, flexible manufacturing operations. In theory, customer orders are fed directly to the plant and the product is produced the next day. These manufacturing systems have been called "mechatronics" (20), and "FCIM" for flexible computer integrated manufacturing (21). Such visions are not so futuristic in that elements exist in manufacturing operations today. Product development ramifications include: a) higher capital investments, b) the need for product, process, and systems expertise, and c) the ablity to economically offer a wider array of product options and thus satisfy market segment requirements.

E. Purchasing

The purchasing function (materials procurement) is playing a larger role in new product development. This is brought about by pressure for higher quality, lower costs and reduced inventory. Thirty years ago, a typical manufacturer's purchases equaled about 30% of total company revenues. Purchased content has gradually increased, so that today the percentage is closer to 60%. "In today's environment, product development must become a cooperative venture by the primary developer and its key suppliers" (22). Industry experts recommend placing purchasing staff near the engineering department, and to rotate engineers into purchasing positions as part of a career development program (22).

The statistician and management consultant, W. Edwards Deming, puts heavy emphasis on purchasing's role. Two of his five tenets for success are:

- Establish long-term ties with select suppliers; don't award contracts on price tag alone.
- Foster teamwork and dismantle the barriers that divide disparate departments (23).

G. Marketing

Earlier discussions implied marketing plays a key role in new product development. For example, sucessful products are ones that satisfy the wants and needs of customers, and product innovations are generally the result of need-pull rather than technology-push. Good input on market requirements is very important during formation of the new product concept.

Understanding the market is as much of an art as it is a science. Studies have shown that customers have a hard time articulating future needs (17). Sophisticated models have been used to predict market demand, such as the use of sales wave experiments and conjoint analysis (24). These approaches have had mixed results. There is an ongoing debate over the effectiveness of focus groups in predicting market behavior (25)(26)(27).

One study showed that innovative companies learn much about the market by developing a rapport with leading edge customers (10). These customers make suggestions on new design features, and are willing to test out prototype models. Other methods used to obtain market insights are customer surveys, field observation of customer requirements, and the use of market experts (17)(28).

III. CORRESPONDENCE

Upon completing the literature search, this author had a greater appreciation of the important elements of product development programs. However, I was not confident of priorities, nor was I sure of the extent to which the duration and efficiency could be improved. There was no immediate answer to the intriguing reports of Japanese firms taking far less time to develop new products.

At this point, Dr. Kocaoglu suggested I correspond with various scholars and researchers with first hand experience in the private sector. As the editor of IEEE Transactions on Engineering Management, Dr. Kocaoglu had good contacts in the academic community. Letters were written to his contacts, and to names encountered during the literature search. With one exception, responses were received from all correspondents. The exception being Dr. Tomoo Ishihara, Director General of the Japan Automobile Reseach Institute.

Results greatly exceeded expectations. Copies of all the correspondence are included in the Appendix behind tabs 1-5. Although the results are summarized in the following discussion, it is recommended that the reader review the correspondence to gain further insights.

The input of each respondent is reviewed below. In some situations, additional technical references are cited to support the respondents observation.

A. Dr. Takeshi Kawase

Dr. Kawase is a professor in the Department of Administration Engineering at Keio University in Japan. My letters to him and his replies are found behind tab 1. My introduction letter is typical of that sent to the other correspondents.

Key observations by Kawase were:

1. Product development in Japan is taken very seriously. It is compared to fighting a war. Competition is intense within Japan as well as in international markets.

2. Because of societal differences, Japanese workers are willing to work on Saturdays and holidays to meet tight schedules. Schedule delays are not easily accepted by workers or management.

3. Japanese firms have better internal communications and product development teamwork. Informal communication is often used to assist downstream activities. "Japanese seem to lack the concept of contract. They tend to do business on a trust basis."

4. Engineers receive cross-training in sales and production.

5. Product development stages are overlapped, with parallel activities occuring early on.

6. CAD/CAM is used extensively. It is strongly supported by management because of productivity advantages, and a general shortage of engineers.

7. Engineering activities will remain centralized in Japan even though manufacturing operations are moving to other countries. Distant manufacturing operations may have a long term detrimental affect on product development.

8. In some situations, part supplier engineers work full time at the host companies product development center.

B. Dr. Kioshi Niwa

Dr. Niwa is the director of the advanced research laboratory for Hitachi Ltd. of Japan. Basic research is conducted at this laboratory, with no immediate/short term product development objectives. His letters are found behind tab 2.

Niwa had little to add about the development cycle for automobiles, because Hitachi does not make autos.

Two noteworthy observations were made. First, he thought that engineering productivity is actually better in the U.S. than in Japan. Second, he felt that short development cycles were the result of top management priority, rather than the result of the effort of individual engineers.

On the surface, Niwa's comment on productivity seems to contradict the notion of faster development cycles in Japan. However, there is support for his contention. While the Japanese use CAD/CAM extensively, they have been slow to adopt other forms of office automation (9)(29). Thus it is possible Japanese engineers are less productive on a comparison of task performance. If this is true, then in a broad sense, one could link Japanese success to management.

C. Dr. Robert Latorre

Dr. Latorre is a professor at the University of New Orleans. He received his masters and Ph.D. in engineering from the University of Tokyo. He was an associate professor at the University of Tokyo from 1986 to 1987. His letter and a related article is found behind tab 3.

Latorre's observations were:

1. Automobiles are strictly inspected in Japan, and large fines are assessed to older vehicles. Consequently, marketplace turnover is higher and there are few cars older than three years. This has forced auto companies to have shorter product development cycles.

2. As consumers, the Japanese pay close attention to detail, and are particularly interested in technical innovations. Automakers must quickly adopt the latest advancements or lose customer loyalty.

3. Managers in Japan are more knowledgeable of technology, and are more apt to exploit it.

D. Dr. Robert Cutler

Dr. Cutler is a senior staff associate at the National Science Foundation. He was a visiting Fulbright research scholar at the University of Tokyo in 1986 and 1987. His response to my inquiry is found behind tab 4.

Cutler's area of expertise is called "technology transfer," which is the process by which research findings and other sources of new information is transferred to product applications.

Cutler has found that the Japanese are much more effective at applying new technology. Much of that technology has its origin in the United States and Europe. Japanese companies make better use of U.S. university research than the U.S. does. This is brought about by a environment and culture in Japan which encourges shared information.

Cutler's recommendation is for U.S. companies to stay abreast of university research findings, and to share the findings among themselves. He also feels Americans should be more active in professional societies. Cutler was quoted in a Massachusets newspaper as saying " Japanese professional societies--particularly in communications and electrical engineering--are hotbeds of technology exchange, he said, with lab results often freely disseminated in meetings, making for less duplication of effort." That newspaper article is found at the end of tab 4.

E. Unnamed U.S. Auto Executive

During the course of this investigation, I had the opportunity to discuss new product development activities with a director of product planning for a major U.S. auto company. This executive had many interesting comments, but wished to remain anonymous.

The executive said all of the U.S. auto companies have aggressive plans to reduce the duration of product development cycles. His key observations were:

1. The studies of product development efficiency by Kim Clark of Harvard are highly regarded, and considered accurate. The executives' company contributed data to the study. Their performance is now much better than that reported in the study. Clark's findings are covered in the next section of this report.

2. The joint ventures between Japanese and U.S. auto companies have been good learning experiences, and equally profitable to both parties.

3. New product development is considered a competitive advantage. Time is considered a competitive advantage.

4. It is sometimes necessary for engineers to work extra hours to meet tight schedules. U.S. auto companies pay an overtime premium to entry level engineers, and a straight time premium to mid-level engineers. Senior engineers are compensated for extra work in other ways.

5. Fundamentally, there are just three variables when schedules are in jepardy: product quality, schedule extension, and development costs. His company now considers the first two variables as constants, and not subject to change. Their only alternative, therefore, is to add resources to meet the schedule.

6. In general, quality does not suffer because of shorter development cycles. Greater cooperation is required with short development cycles. Downstream stakeholders receive information earlier, more frequently, and in smaller batches. The net result is fewer surprises and better quality.

F. Dr. Kim Clark

Dr. Clark is a professor at Harvard Business School. He is conducting a research program on product development efficiency in the world auto industry. His letter and four draft working papers, are found behind tab 5.

Clark's work is comprehensive, perceptive, and (at least to this author) fascinating. "The data cover 29 major new vehicle development projects in 20 companies. The companies in the sample (8 in Japan, 3 in the U.S., and 9 in Europe) accounted for about 75 percent of automobile production in the world in 1987." The research papers are highly recommended reading for those interested in product development. I have summarized and charted some of the more interesting data in Figures 1 and 2 on the following pages. Key are observations are:

1. The Japanese have shorter development cycles, and use less labor to develop new products.

2. About 60-70% of the Japanese advantage is related to management. They use an organization structure which is best suited for new product development, and they overlap

NEW PRODUCT DEVELOPMENT PROGRAM PROFILES

DRAFT SUMMARY DATA ON WORLD AUTO INDUSTRY

VARIABLE	TOTAL	JAPAN	U.S.	EUROPE
I. SURVEY PARAMETERS				
A. NUMBER OF PROJECTS	29	12	6	11
B. YEAR OF INTRODUCTION	1980-87	1981-85	1984-87	1980-87
C. AVERAGE VEHICLE PRICE (1987$)	13,591	9,238	13,193	19,720
D. AVERAGE NUMBER OF BODY TYPES	2.1	2.3	1.7	2.2
II. PREFORMANCE MEASURES				
A. PRODUCT DEVELOPMENT LEAD TIME (MONTHS)				
1. MINIMUM	35.0	35.0	50.2	46.0
2. MAXIMUM	97.0	51.0	77.0	97.0
3. AVERAGE	54.2	42.6	61.9	62.6
4. ADJUSTED AVERAGE*	N/C	46.6	N/C	59.6
B. ENGINEERING HOURS (THOUSANDS)				
1. MINIMUM	426	426	1041	700
2. MAXIMUM	7000	2000	7000	6545
3. AVERAGE	2577	1155	3478	3636
4. ADJUSTED AVERAGE*	N/C	1689	N/C	3204
III. PROJECT STRATEGY: PARTS				
A. NEW/OLD PARTS RATIO				
1. UNIQUE TO PROJECT	74%	82%	62%	71%
2. NONUNIQUE	26%	18%	38%	29%
B. SOURCE OF UNIQUE PARTS				
1. IN-HOUSE DESIGN	62%	48%	85%	65%
2. SUPPLIER DESIGN	38%	52%	15%	35%
IV. ORGANIZATION STRUCTURE TYPE				
A. FUNCTIONAL STRUCTURE	6	0	1	5
B. LIGHT-WEIGHT PROJECT MANAGEMENT	19	8	5	6
C. HEAVY-WEIGHT PROJECT MANAGEMENT	4	3	0	1

Notes:

1. The above data was extracted from the draft reports in the Appendix by Dr. Kim Clark of Harvard Business School.

*2. The adjusted average values were computed by Dr. Clark, and account for differences in parts suppliers' role, off-the-shelf parts, and vehicle complexity. Adjusted values for U.S. auto companies have not been calculated (N/C) as yet.

FIGURE 1

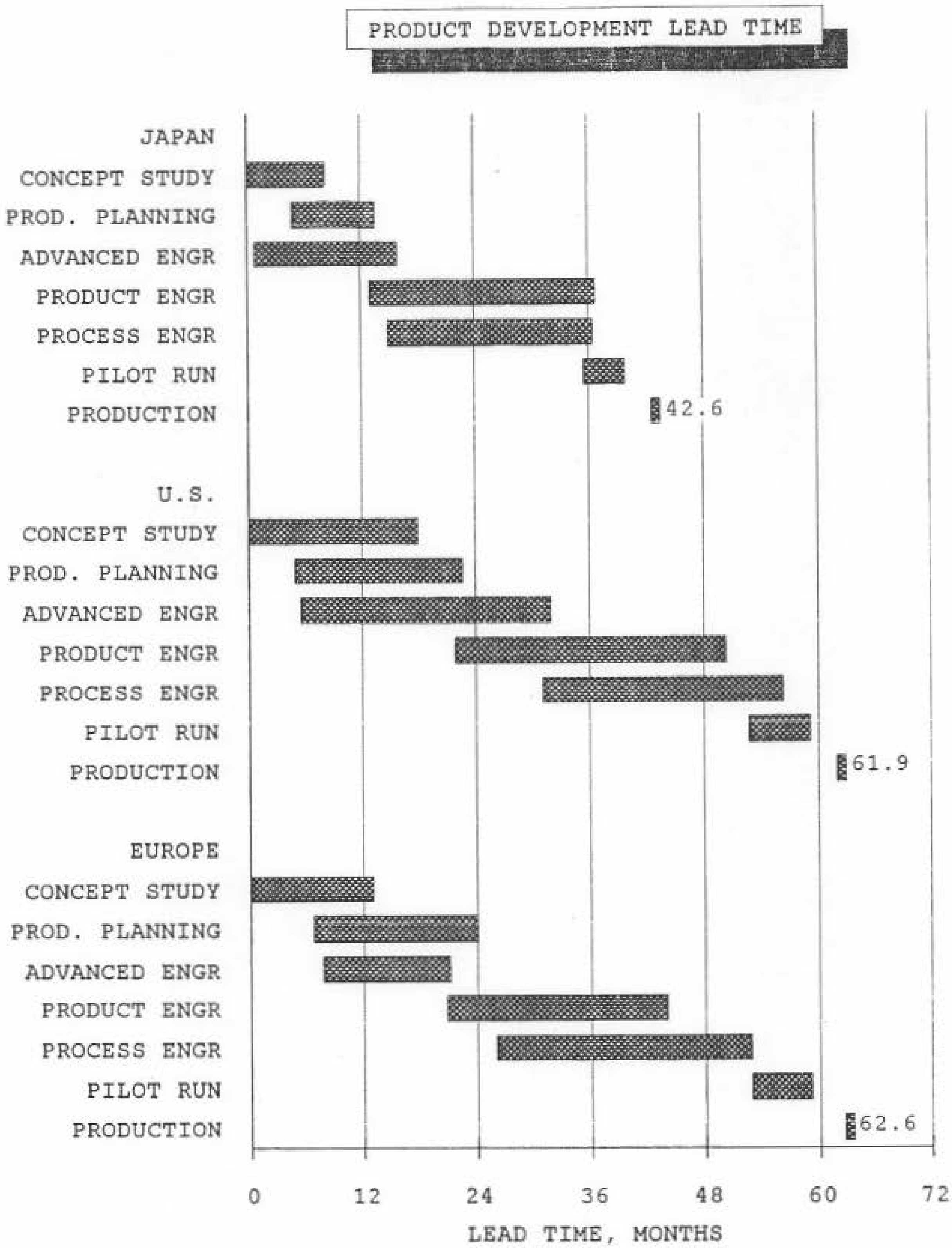
PRODUCT DEVELOPMENT LEAD TIME
JAPAN
CONCEPT STUDY
PROD. PLANNING
ADVANCED ENGR
PRODUCT ENGR
PROCESS ENGR
PILOT RUN
PRODUCTION
42.6
U.S.
CONCEPT STUDY
PROD. PLANNING
ADVANCED ENGR
PRODUCT ENGR
PROCESS ENGR
PILOT RUN
PRODUCTION
61.9
EUROPE
CONCEPT STUDY
PROD. PLANNING
ADVANCED ENGR
PRODUCT ENGR
PROCESS ENGR
PILOT RUN
PRODUCTION
62.6
0
12
24
36
48
60
72
LEAD TIME, MONTHS

FIGURE 2

the various project stages so that activities are conducted in parallel. The Japanese use a matrix form of organization structure for new product development. "In the best of the Japanese projects, a heavy-weight project manager leads a multifunctional team, in which problem solving cycles are overlapped and closely linked through an intensive, dialog mode of communication."

3. Companies in the sample which used a purely functional organization structure tended to have longer development cycles and expend more labor. "Functional organizations drew people from many disciplines, subdivided tasks significantly, and thus tended to be quite large." The average heavy-weight project management team would require 333 engineers, whereas a functional organization would require 1,421 engineers!

4. As Figure 2 illustrates, there are several stages in the product development cycle. Clark concludes that "overlapped timing of upstream and downstream activities is associated with shorter lead times in development." The Japanese begin to make tooling shortly after design is started. Compare the process engineering stages in Figure 2. This is the stage where tooling design and fabrication begins. The process stage typically starts at 15 months in the Japanese cycle, 31 months in the U.S. cycle, and 26 months in the European cycle.

5. Overlapped timing of project stages requires interdepartment coopertion and frequent communication. "If

we look at the release of engineering drawings to die development groups, for example, we find that the Japanese release preliminary information more frequently; three releases was common practice."

6. About 30-40% of the Japanese advantage is related to project strategy, which Clark describes as the development of component parts. This involves supplier participation, unique parts, and off-the-shelf parts.

7. The Japanese have a stronge supplier system. "Studies have shown that the Japanese auto companies deal directly with 200-300 'first tier' suppliers who possess significant engineering and manufacturing capability." Japanese suppliers are heavily involved in the design process, and are given a lot of design latitude (which Clark describes as the black box format).

8. In-house design of unique parts, which is a typical U.S. practice, creates project complexity and tends to reduce productivity. "These results suggest that the combination of a high fraction of unique parts and significant engineering work in-house creates a complex planning process that requires more time to complete." "Further, there is some evidence from the interviews that project managers and engineers found external suppliers easier to work with than their internal parts divisions. In several cases, managers suggested that working with the internal parts suppliers gave the project less control over

the engineering work and involved them in a more bureaucratic process than working with outside suppliers."

9. The use of state-of-the-art engineering technology does not seem to be a factor in Clark's comparisons. Virtually all of the firms contributing to the survey extensively used technology, such as CAD/CAM.

In the above discussion, I have attempted to summarize about 200 pages of Clark's detailed research data. I hope his results are not substantively distorted.

A final interesting observation is that Clark's study seems to empirically support the assertions made earlier by Kawase and Niwa.

IV. HYSTER EXPERIENCE

Hyster Company has made significant progress in reducing the duration of the product development cycle. This is worthy of discussion, even though it will not be covered in detail for competitive reasons.

Hyster actions are consistent with the best practices described elsewhere in this report. In this respect, the Hyster experience serves to underscore those good practices. This is not to say that there is not room for improvement. As a result of this investigation, it is even more apparent that there are opportunities for further gain. Product development should be appraised continually for efficiency improvement.

As background, Hyster was subjected to a turbulent business environment beginning in the early 1980's. Worldwide sales of material handling goods were at a low plateau, while at the same time Japanese manufacturers began exporting lift trucks to the U.S. and Europe. Japanese products were not as sophisticated, but were of high perceived quality and were low priced. Supply outstripped demand and significant list price discounts were endemic.

In this environment, many U.S. and European competitors suffered severe financial hardships, including scaled down operations and bankruptcy. Yet Hyster has endured and even prospered. Hyster is currently rated as the third largest material handling company in the free world (30).

There are many factors involved with the Hyster success story, one of which was our progress with new product development programs, as depicted in Figure 3 below.

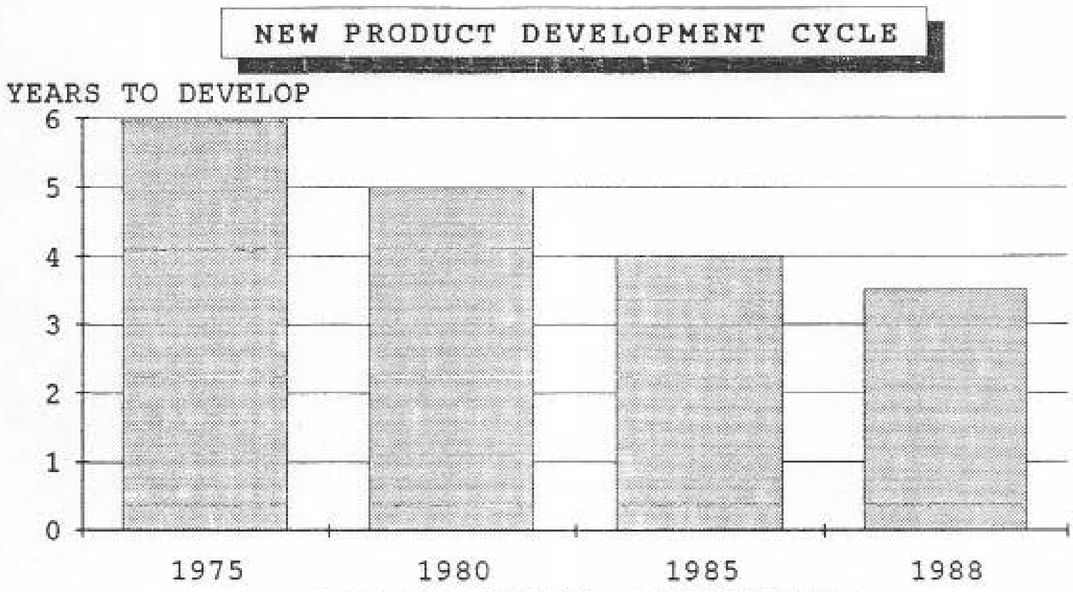

FIGURE 3

The management practices which made this progress possible are outlined as follows:

- A project management form of organization structure is employed, emphasizing the team approach to new product development.
- New engineering technologies are applied, such as CAD/CAM, finite element modeling of structures, and computerized data management systems.
- Common parts are used in different models when it is economically attractive to do so.

- Manufacturing, purchasing, and marketing functions are involved early in the design process. Purchasing is receiving greater emphasis, and closer vendor ties are cultivated.
- Proposed projects are scrutinized for financial viability, and closely monitored thereafter.

For competitive reasons, it is not be prudent to discuss further details.

V. CONCLUSIONS

Three methods were used to evaluate the duration and efficiency of new product development programs. First, a comprehensive literature search was conducted. Second, information was received from key researchers and scholars by personal correspondence. And last, the product development progress of Hyster Company was reviewed. As a result of this investigation, a consistent picture of efficient programs emerges. Moreover, the evidence supports the notion that significant reductions in duration and labor are possible -- in the order of magnitude of 50%.

Efficient new product development programs are characterized by:

1. Good management - A project management form of organization structure, overlapping of project stages, and a general commitment to tight schedules. Manufacturing, purchasing, marketing, and finance functions should be involved in the early stages of development. Good management is by far the most important factor.
2. Supplier involvement - Encourage their participation in the development process. Purchased content represents an ever increasing portion of product costs.

3. <u>Application of new engineering technology</u> - CAD/CAM and other productivity enhancing technologies must be exploited to remain competitive.

4. <u>Training</u> - Communication and team building skills are needed. Cross-training of engineers in other functional areas can help break the barriers of communication and increase knowledge.

This is merely an outline of the most important factors. There are many other considerations covered elsewhere in this report.

As a final comment, the fundamental issue of technology transfer deserves reflection. Engineering organizations have a vested interest in staying abreast of technological developments -- indeed, corporate survival is often at stake. Organizations should be prepared to apply that technology to new products. Research developments should be monitored, and participation should be encouraged in the academic community and professional societies.

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