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# UTILIZATION OF PRODUCT DEVELOPMENT TOOLS AND METHODS: JAPANESE SURVEY AND INTERNATIONAL COMPARISON

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## Abstract

This paper reports a questionnaire survey on utilization of various tools and methods in the product development process of Japanese manufacturing industries. After its background and purpose are described, the result is discussed on their awareness and utilization, the relationships with promotion activities, types of industry, organizational structure, and product development cycle, etc. Further, the gotten result is partially compared with the preceding studies in some Western countries to reveal the underling mechanism in promotion of product development tools and methods.

*Keywords*: *integrated product development, introduction of methods in industry, concurrent engineering.*

## 1 Introduction

The prosperity of manufacturing industries is a key factor determining the raise and fall of a nation. The stream of concurrent engineering, which is a main branch of design engineering, had been initiated around 1990 by reflecting the rise of Japan's manufacturing in 1980s and for enhancing productivity performance in Western countries. Concurrent engineering focuses on the integrity of products across the viewpoints such as quality, cost and delivery. Its trend has recognized various design methods, such as quality function deployment (QFD), design for assembly (DFA), Taguchi method, as effective means. Simultaneously various digital engineering tools, such as CAD, CAE, PDM, etc., have become widely available and enhanced in performance under down-sizing of computers, etc. They have become indispensable in some directions of today's product development. Behind the potential power of those tools and methods, their utilization may be obstructed or postponed due to various reasons such as history, culture, and organizational structures of respective industries and companies. While the cause and effect on the current situation of Japan's manufacturing are obscure, it has been under various difficulties more than ten years after the big success in 1980s. Even though it is affected by various outside causes such as reformation of manufacturing business styles in Western countries, the raise of East Asian countries, etc, they are at least unavoidable causes [1]. Rather, it must be a right direction of design engineering to investigate what are the current practices of product development in Japan and other countries for understanding the role of tools and methods in concurrent engineering afresh.

This paper reports the result of a questionnaire survey on utilization of product development tools and methods. Under the above standpoint, we performed a questionnaire survey to manufacturing firms in Japan with reflecting the development of various tools and methods after 1980s. This survey had been motivated by similar surveys performed in United Kingdom [2], New Zealand [3], and Sweden [4], respectively. While they were aimed to investigate the effects and promotion of concurrent engineering and related tools and methods, some of

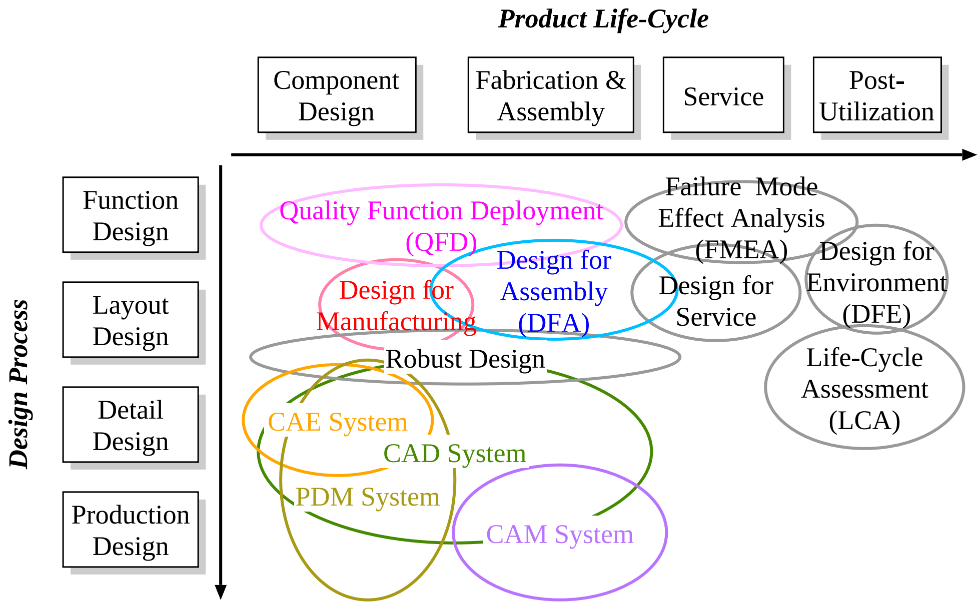


Figure 1 Application areas of tools and methods over product life-cycle and design process (Arranged from [5])

tools and methods, such as quality function deployment (QFD), Taguchi method, had been originally developed in Japan. Thus, the comparison between Japan's survey and Western surveys is expected to bring some new insights on innovation of product development process. In the followings, the situations and conditions in deploying various tools and methods into product development are reviewed, the contents of questionnaire are described, their analysis and comparison are performed, and some conclusions are given.

## 2 Tools and Methods for Product Development

While design is a key of product development, it is subsidiary in inventing new values and functions or renovating existing ones, is related to their systematization or integration, or to organize its process. Since design is an inherent activity of mankind, discussion of frameworks and methods for improving or rationalizing design process had not been an explicit major issue in engineering. However, as the contents of artifacts, such as machines, products, have become more complicated and massive, allocation and enforcement of design knowledge and process have become unavoidable issues in manufacturing industry. Additionally, as various digital engineering tools such as CAD systems have becomes widely available under the progress of information technology, their utilization has become an important issue for enhancing product development performance.

Figure 1 roughly shows a map of tools and methods for product development over the design process and product life-cycle. While some of them originated in 1970s, others were formed in 1990s or later under the movement of concurrent engineering. The coverage of tools and methods has been gradually spread so as to support a series of phases and aspects more widely and in more integrated way. When considering that product development is an integrated activity, it should be an essentially important view not only to utilize respective ones, each of which was developed independently from the others, individually but also to systematically organize the overall process of product development by selectively utilize ones, which are necessary and effective for a specific project, from available ones.

As aforementioned in Introduction, the preceding surveys carried out in some Western

Table 1 Distribution and collection of questionnaire sheets

| | # of companies | # of sheets |
|---|---|---|
| Sent sheets | 289 | 1167 |
| Returned sheets | 118 | 221 |
| Return rate | 41.8% | 18.9% |

Table 2 Breakdown of returned sheet by types of industry

| Types of industry | # of returned sheets |
|---|---|
| Raw material for industries | 25 |
| Electronic parts | 22 |
| Machine components | 15 |
| Industrial equipments and machinery | 20 |
| Industrial facilities | 59 |
| Information equipments | 15 |
| Automotive | 6 |
| Electric and electronic consumer appliances | 22 |
| Other | 37 |

countries [2, 3, 4] aimed to explore any guiding principles for systematic deployment of tools and methods through investigation and analysis of current utilization in product development practices. This is also a matter of Japan's manufacturing when considering that various new tools and methods have been developed in the last decade and that there are some struggles for improving its performance under the transformed economic circumstance. Beyond the conditions in a particular country, since the outcomes of design engineering continuously bring new means for innovating product development process and circumstances of product development are continuously transforming under social growth and economical development, how to utilize tools and methods and how to promote their utilization should be also universal and everlasting issues of design engineering.

## 3 Distribution and Collection of Questionnaire

The questionnaire survey on Japan's manufacturing firms was carried out by sending sheets to manufacturing companies by mail and requesting to return their filled ones by an assigned date in the autumn of 2002. The companies that sheets were sent to are ones that offer employment opportunities to the students of Department of Mechanical Engineering, Osaka University, ones that are listed in a company information magazine published by a regional branch of the Japanese Society of Mechanical Engineers, and ones that are supplementally added from graduates of our laboratory at Osaka University. Since some Japanese manufacturing firms simultaneously produce different kinds of products, for instances in the cases of home appliances, heavy industries, etc., five, three or one sheets were sent to each company and it was asked to distribute each to different sectors according to the type of industry. As Table 1 summarizes the numbers of sheets sent out and returned, the return rate was fairly high as this kind of questionnaire surveys. Table 2 shows the breakdown of 221 sheets returned by types of industry. Figure 2 shows the the size of each company that returned a sheet

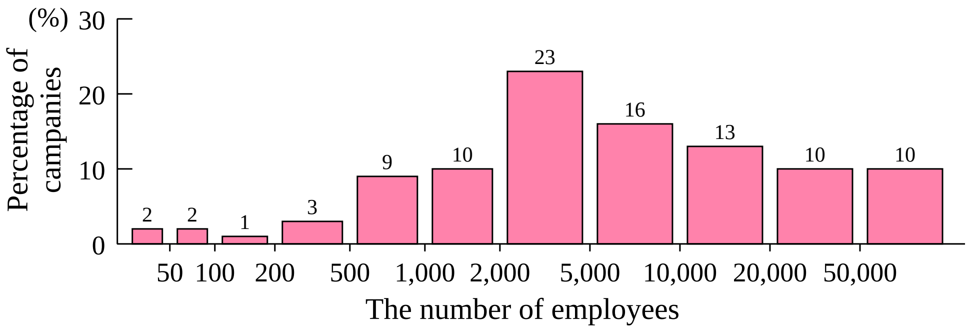


Figure 2 The size of companies in the number of employees

by the number of employees. As a result of the above selection of companies, their size tends to be larger than the actual distribution in Japan.

The questionnaire items are prepared by referring the items used in preceding ones [2, 3, 4] and by adding new items. The items are categorized into the following directions:

(i) Type of products and business, and their scale.
(ii) Overall circumstances of product development process.
(iii) Utilization of respective tools and methods.
(iv) Implementation of respective design phases.
(v) Organizational structure.
(vi) Certification system of quality control, etc.

The reason why the items of (i) and (ii) are included into the questionnaire as well as ones of (iii) is for understanding their mutual relationships. In the analysis of survey, questionnaire answers are divided into some groups according to a type of industry, the number of engineers who are involved into a project from planing phase to production launch phase, and the duration of product development of product(s), for revealing the relevant correlations between utilization of tools and methods and its background factors.

The questionnaire sheet is fifteen pages, and includes fifty items as major questions. Check-mark style, in which a set of choices are prepared beforehand and each responser checks one of them, was used for facilitating answering to the sheet. The total number of check-mark boxes was reached to 817. It was expected that a responser could fill out the sheet in a hour.

# 4 Survey and Analysis

## 4.1 Utilization of tools and methods in Japan

Figure 3 shows the result on how many companies or divisions are aware of or utilize particular tools and methods, which are listed in the questionnaire sheet. First, it seems that the both rates of awareness and utilization are relatively high in average. This might be caused by the possibility that each questionnaire sheet was filled by engineers who are charged into promotion of tools and methods for product development. We received some outspoken comments that real percentage of awareness and utilization may be something like one tenths of the gotten result from several manager-class engineers. Beyond such comments, the results shown in Figure 3 are interpreted as follows.

In general, the tools and methods that more companies or divisions are aware of are utilized by more companies or divisions. When considering that it is not suitable in both aspects of time and cost that all tools and methods are tried to be utilized in a single project, that appropriate tools and methods depend on the type of industry, the scale of business, etc. and so forth, it

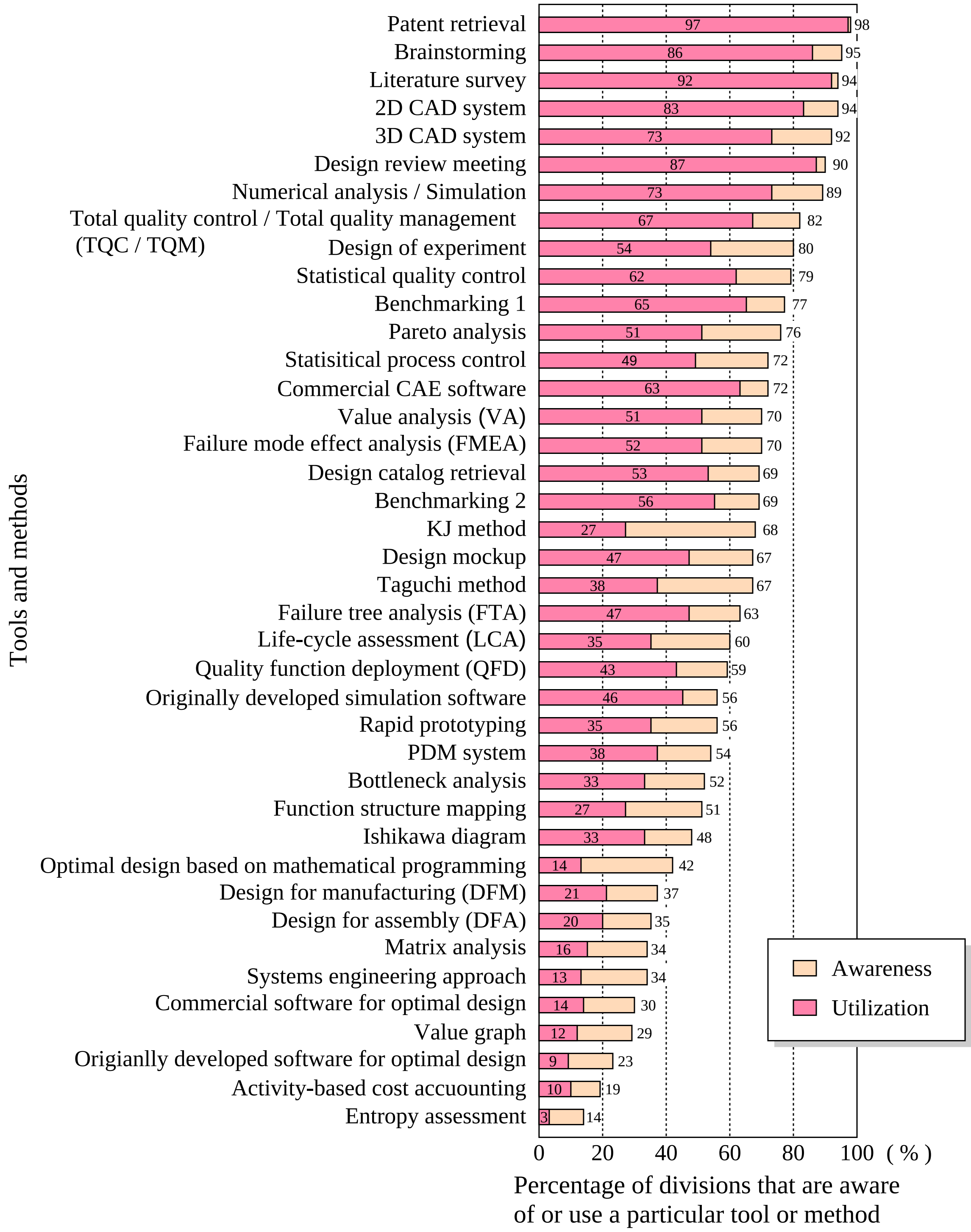


Figure 3 Awareness and utilization of respective tools and methods

cannot be viewed as a problem that utilization rate of each method or tool is low. However, the fact that awareness rate is low indicates that utilization of tools and methods in product development process is not rationally organized, that is, which ones should be utilized or not is not systematically determined. This point must be a problem to be overcome.

Characteristics on awareness and utilization of particular tools and methods are summarized as follows:

- Methods for facilitating team communication, such as brainstorming, design review

meeting, and methods for gathering information, such as patent retrieval, literature survey, benchmarking, design catalog retrieval, are widely utilized in general.
- While CAD systems and simulation techniques are well introduced, tools and methods, such as quality function deployment (QFD), life-cycle assessment (LCA), which should be utilized in the early phases of the design process, are not so much utilized.
- It is a tendency that utilization rate of ones that require much effort in introduction are relatively low in comparison with their awareness.
- Introduction of optimal design based on mathematical programming is a typical case of such tendency. Its reason may be that optimal design indispensably requires original modeling for computational synthesis beyond application of various simulation techniques to engineering analysis.

Figure 4 shows the rate of ones who answered that a method or tool is effective within ones who answered that it is utilized. In general, even though this effectiveness rate of a particular method or tool is high, the rate of its utilization is low. Among various tools and methods, for instances, regarding Taguchi method and rapid prototyping, more than 70 percent users stated that they are effective. Even under this high rate of effectiveness, their utilization is about 35 percent but their awareness is more than 65 percent. This indicates that effectiveness of tools and methods must be somehow promoted to practice in manufacturing.

### 4.2 International comparison of utilization of tools and methods

Figure 5 shows the comparison of utilization rate of tools and methods, which are common to surveys carried out in United Kingdom [2] and New Zealand [3], selected from ones listed in Figure 3 among Japan and those two countries. As aforementioned, deployment of various tools and methods has been affected by trend of concurrent engineering after the latter half of 1980s and the difference of productivity performance among countries. Since the absolute values of utilization rate may be affected by industrial structure of each country or else, it must be inappropriate to discuss them individually. However, any meaningful fact may be hidden under the overall tendency.

In Figure 5, various tools and methods are sorted in the order of higher utilization rate in Japan. Utilization rates of quality function deployment (QFD) and Taguchi method, which were originated in 1970s of Japan, are higher than ones of United Kingdom and New Zealand. But, utilization rates of design for assembly (DFA) and design for manufacturing (DFM) in Japan are remarkably lower than ones of United Kingdom and New Zealand. This disparity indicates the following fact on promotion of tools and methods in Japan:

- While various methods and their effectiveness are widely recognized in the academic field of systematic engineering design, it might be true that advances in research are not transfered to the practice as its total shape.
- While various efforts are taken for enhancing product development performance, it must be sure that such efforts in industry still remain in empirical deployment.

While these points are nothing but hypotheses, the result shown in Figure 5 is interpreted that systematic promotion of tools and methods must be essentially important. While there is an opinion that DFA and DFM are not necessary when manufacturing is tacitly strong enough without any explicit tool or method, this kinds of view must be a risky idea.

### 4.3 Backgrounds such as organizational activities on utilization of tools and methods

The analysis shown in the previous subsection indicates that organizational activities to promote concurrent engineering or else may affect the deployment of tools and methods into

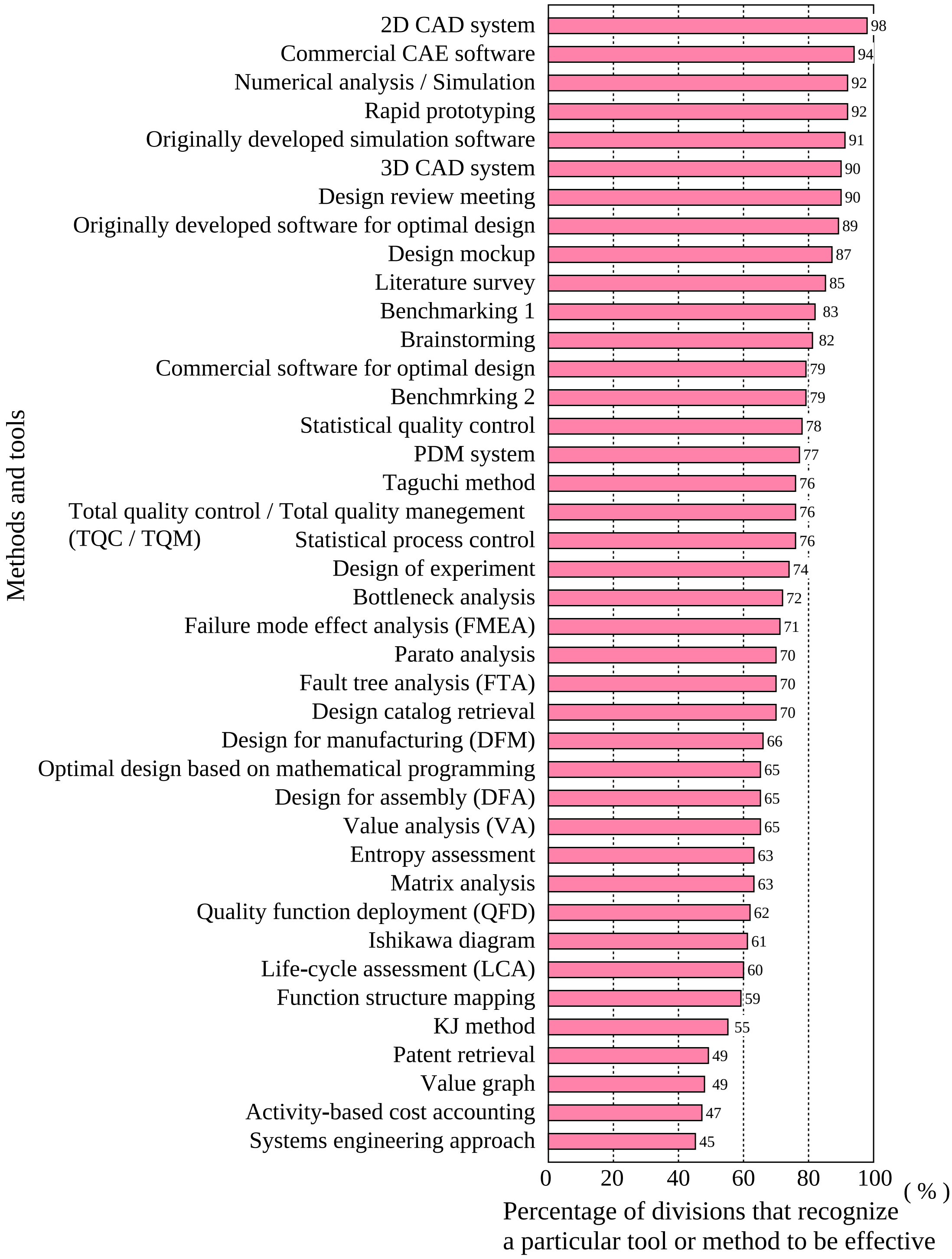


Figure 4 Effectiveness of tools and methods under their utilization

practice. Among all answers of Japan's survey, 60 percent responsers stated that they were performing any activities on concurrent engineering. Figure 6 shows how such activities affect utilization of tools and methods. It is confirmed that the utilization rate of every method or tool, except commercial software for optimal design, is higher under such activities. This is an evidence that shows the importance of organizational promotion toward strong product development process.

Regarding to questions on whether any division or engineer(s) are assigned to support the

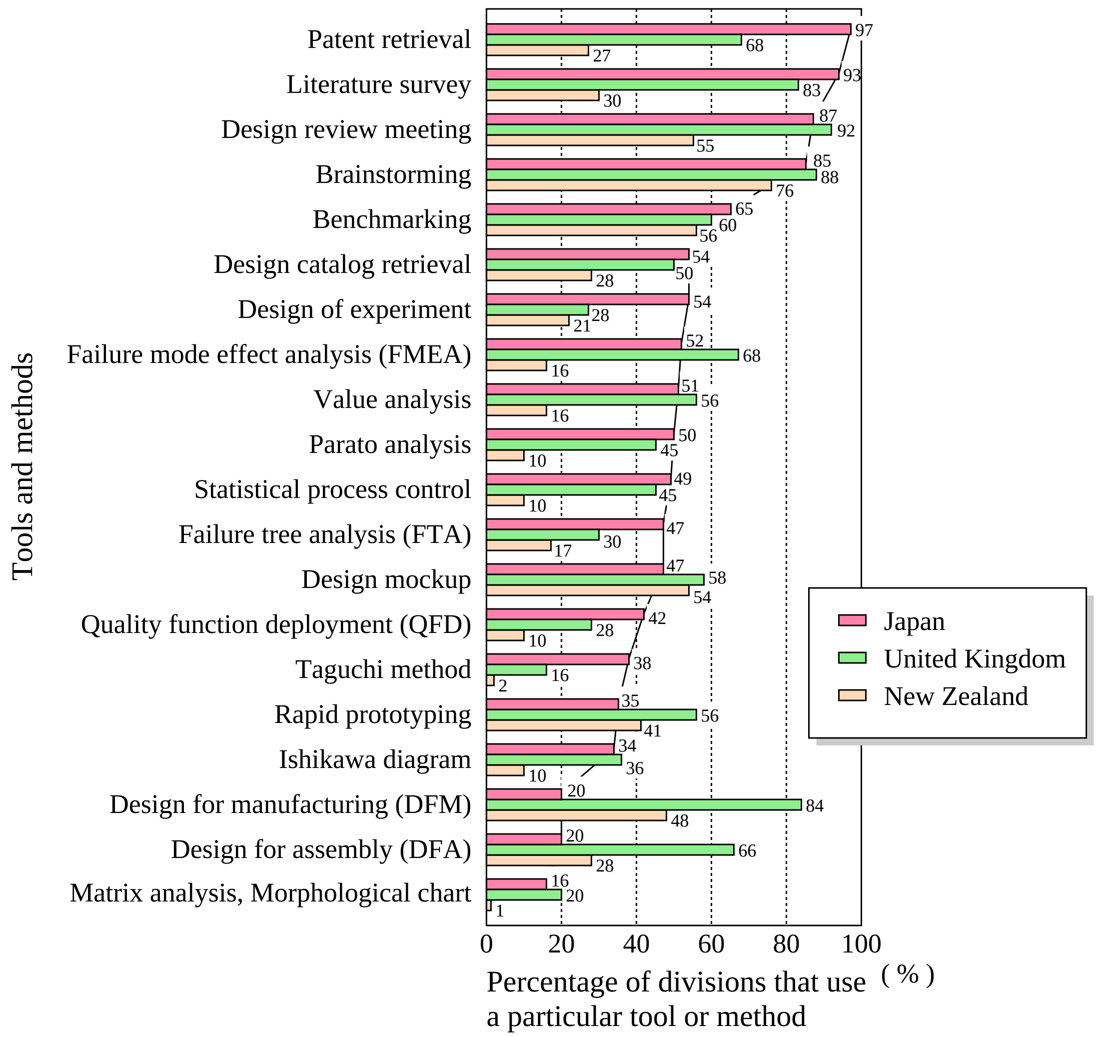


Figure 5 Comparison of utilization of tools and methods among Japan, United Kingdom, and New Zealand

introduction of various tools and methods, 23 responsers percent answered that any division or engineer(s) is allocated within a product development team. 48 ones percent answered that a company arranges any special division or specialist(s) for supporting product development process. 9 percent ones answered that a company employs any external consultant for supporting product development team(s). These indicates that most of companies take any efforts for enhancing product development performance. On the other hand, regarding to procedures in product development, only 19 percent of companies establish any guideline on which tools and methods should be utilized at individual phases of product development process respectively. This means that the above efforts do not still reach to systematic activities in which the overall process of product development is totally organized for instance by specifying guidelines, etc. That is, the circumstance indicated by the international comparison shown in the previous subsection is endorsed with this result.

### 4.4 Differences in utilization viewed from types of industry

While some points revealed in the preceding subsections were similarly indicated by the questionnaire surveys [2, 3, 4], the study in New Zealand [3] pointed out that there is no universal model on how to utilize tools and methods that is applicable to all types of industry.

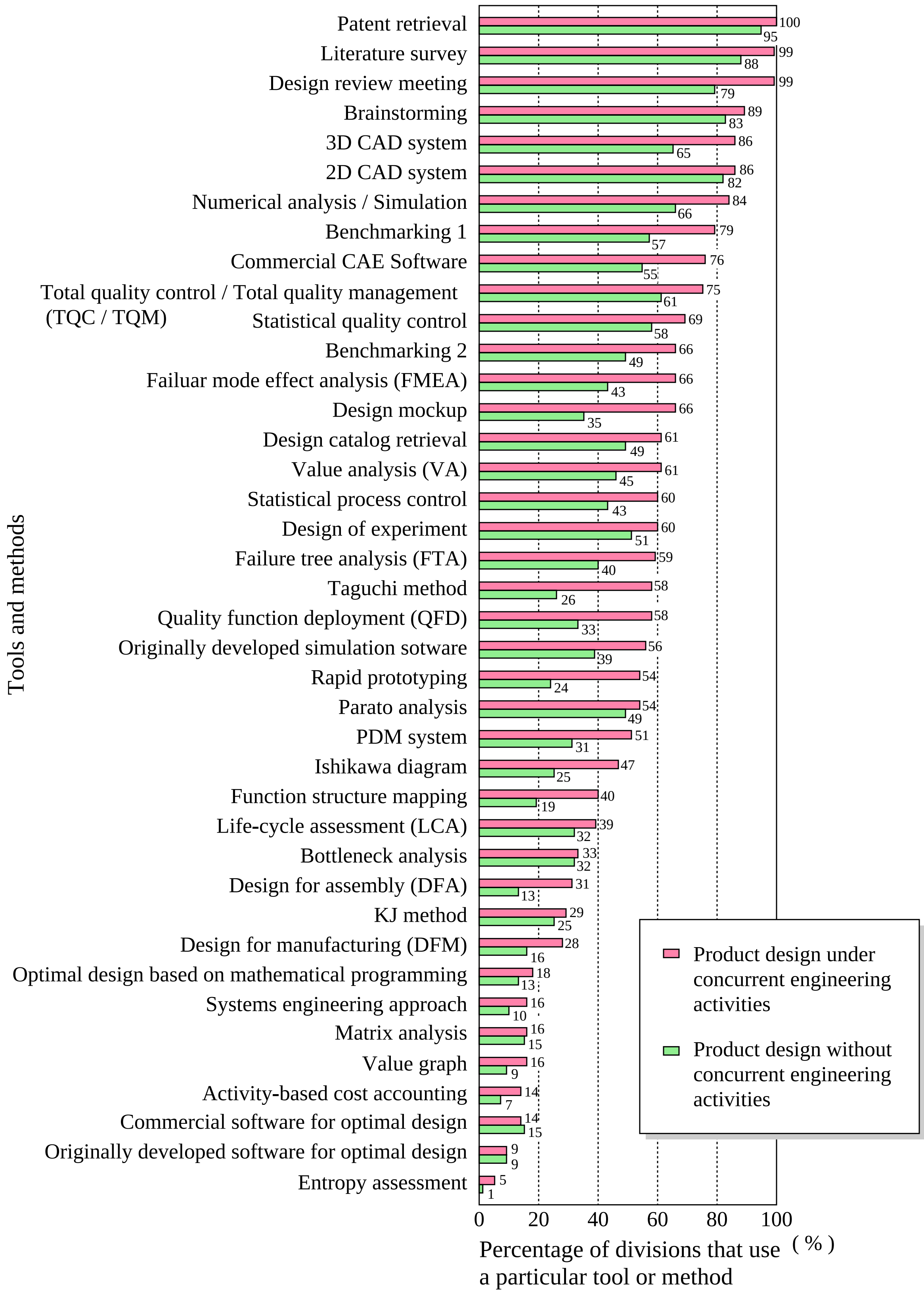


Figure 6 Differences in utilization of tools and methods by referring organizational activities for promoting concurrent engineering, etc.

Table 3 Utilization of tools and methods in different types of industry

| Utilization (%) / Types of industry / Tools and methods | Total | Raw material for industry | Electronic parts | Machine components | Industrial equipments and machinery | Industrial facilities | Information equipments | Automotive | Electric and electronic consumer appliances |
|---|---|---|---|---|---|---|---|---|---|
| Brainstorming | 89 | 90 | 89 | 96 | 88 | 87 | 95 | 88 | 96 |
| Design review meeting | 90 | 70 | 93 | 91 | 96 | 93 | 95 | 82 | 96 |
| KJ method | 29 | 17 | 26 | 18 | 26 | 24 | 45 | 47 | 41 |
| Value analysis (VA) | 55 | 40 | 48 | 61 | 78 | 54 | 60 | 81 | 52 |
| Value graph | 13 | 0 | 4 | 10 | 13 | 9 | 15 | 20 | 23 |
| Function structure mapping | 30 | 35 | 21 | 41 | 38 | 26 | 26 | 44 | 29 |
| Quality Function Deployment (QFD) | 46 | 45 | 37 | 52 | 71 | 42 | 53 | 59 | 56 |
| Matrix analysis, Morphological chart | 18 | 5 | 15 | 27 | 19 | 18 | 20 | 31 | 26 |
| Systems engineering approach | 15 | 0 | 15 | 10 | 22 | 9 | 20 | 38 | 19 |
| Design mockup | 50 | 15 | 35 | 45 | 77 | 38 | 78 | 69 | 71 |
| Benchmarking 1 | 68 | 53 | 71 | 74 | 85 | 56 | 90 | 94 | 89 |
| Taguchi method | 41 | 37 | 59 | 64 | 42 | 30 | 75 | 63 | 54 |
| Ishikawa diagram | 36 | 53 | 46 | 38 | 44 | 29 | 50 | 35 | 33 |
| Pareto analysis | 53 | 60 | 64 | 52 | 69 | 44 | 52 | 59 | 56 |
| Bottleneck analysis | 35 | 26 | 33 | 24 | 36 | 36 | 20 | 44 | 33 |
| Fault tree analysis (FTA) | 52 | 30 | 48 | 65 | 73 | 49 | 52 | 69 | 59 |
| Failure mode effect analysis (FMEA) | 56 | 42 | 65 | 74 | 68 | 48 | 60 | 75 | 63 |
| Design for assembly (DFA) | 23 | 5 | 19 | 30 | 35 | 15 | 55 | 47 | 35 |
| Design for manufacturing (DFM) | 24 | 11 | 11 | 30 | 35 | 17 | 55 | 47 | 31 |
| Life-cycle assessment (LCA) | 38 | 15 | 37 | 27 | 48 | 32 | 55 | 47 | 58 |
| Entropy assessment | 3 | 0 | 0 | 5 | 4 | 0 | 5 | 7 | 12 |
| Benchmarking 2 | 60 | 56 | 63 | 68 | 77 | 51 | 70 | 94 | 75 |
| 2D CAD system | 87 | 57 | 79 | 100 | 93 | 96 | 95 | 82 | 81 |
| 3D CAD system | 76 | 45 | 67 | 96 | 85 | 74 | 90 | 81 | 86 |
| PDM (Product Data Management) system | 43 | 16 | 44 | 59 | 42 | 47 | 65 | 71 | 36 |
| Numerical analysis / Simulation | 78 | 56 | 84 | 96 | 92 | 78 | 85 | 94 | 76 |
| Commercial CAE software | 72 | 53 | 73 | 78 | 92 | 78 | 84 | 94 | 74 |
| Originally developed simulation software | 60 | 53 | 64 | 68 | 85 | 56 | 59 | 75 | 61 |
| Other kinds of numerical analysis software | 3 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| Optimal design based on mathematical programming | 19 | 19 | 13 | 28 | 22 | 18 | 33 | 50 | 25 |
| Commercial software for optimal design | 24 | 31 | 20 | 31 | 29 | 18 | 40 | 58 | 20 |
| Originally developed software for optimal design | 16 | 19 | 12 | 23 | 20 | 15 | 33 | 45 | 22 |
| Other kinds of software for optimal design | 3 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rapid prototyping | 39 | 17 | 37 | 55 | 64 | 18 | 74 | 69 | 69 |
| Design of experiment | 59 | 53 | 63 | 68 | 64 | 52 | 81 | 75 | 68 |
| Total quality control / Total quality management (TQC / TQM) | 72 | 75 | 70 | 81 | 92 | 64 | 86 | 80 | 70 |
| Statistical quality control | 69 | 74 | 78 | 75 | 79 | 56 | 75 | 87 | 73 |
| Statistical quality management | 55 | 56 | 74 | 58 | 65 | 42 | 53 | 71 | 63 |
| Activity-based cost accounting | 10 | 0 | 8 | 5 | 17 | 6 | 25 | 25 | 19 |
| Literature survey | 96 | 100 | 100 | 91 | 100 | 94 | 95 | 94 | 93 |
| Patent retrieval | 98 | 100 | 96 | 96 | 100 | 100 | 100 | 94 | 100 |
| Design catalog retrieval | 59 | 42 | 63 | 48 | 58 | 71 | 70 | 50 | 62 |

Table 4　Contribution of tools and methods in their utilization in different types of industry

| Contribution (%) / Types of industry / Tools and methods | Total | Raw material for industry | Electronic parts | Machine components | Industrial equipments and machinery | Industrial facilities | Information equipments | Automotive | Electric and electronic consumer appliances |
|---|---|---|---|---|---|---|---|---|---|
| Brainstorming | 1.91 | 1.95 | 2.04 | 1.91 | 1.87 | 1.90 | 1.79 | 1.80 | 1.81 |
| Design review meeting | 2.17 | 2.29 | 2.27 | 2.38 | 2.19 | 2.05 | 2.05 | 2.43 | 2.11 |
| KJ method | 1.58 | 1.33 | 1.14 | 1.25 | 1.67 | 1.63 | 1.44 | 1.71 | 1.64 |
| Value analysis (VA) | 1.75 | 1.75 | 1.54 | 2.07 | 1.86 | 1.78 | 1.50 | 2.23 | 1.85 |
| Value graph | 1.56 | — | 1.00 | 1.50 | 1.33 | 1.67 | 1.33 | 2.00 | 1.67 |
| Function structure mapping | 1.68 | 1.57 | 1.67 | 1.89 | 1.67 | 1.72 | 1.40 | 1.71 | 1.57 |
| Quality Function Deployment (QFD) | 1.74 | 1.78 | 1.70 | 1.91 | 1.82 | 1.68 | 1.70 | 1.90 | 1.79 |
| Matrix analysis, Morphological chart | 1.70 | 2.00 | 1.75 | 1.83 | 1.40 | 1.58 | 1.50 | 1.60 | 1.86 |
| Systems engineering approach | 1.53 | — | 1.25 | 2.50 | 1.20 | 1.50 | 1.50 | 1.67 | 1.80 |
| Design mockup | 2.17 | 2.00 | 2.11 | 2.50 | 2.25 | 1.96 | 2.29 | 2.36 | 2.45 |
| Benchmarking 1 | 2.01 | 2.00 | 1.85 | 2.24 | 2.05 | 1.85 | 2.05 | 2.31 | 2.00 |
| Taguchi method | 2.00 | 2.00 | 1.94 | 2.14 | 2.09 | 2.05 | 2.20 | 2.30 | 2.21 |
| Ishikawa diagram | 1.71 | 1.30 | 1.85 | 1.63 | 1.82 | 1.60 | 2.10 | 1.67 | 2.00 |
| Pareto analysis | 1.81 | 2.08 | 1.89 | 1.92 | 1.72 | 1.74 | 2.00 | 1.60 | 1.73 |
| Bottleneck analysis | 1.82 | 1.60 | 2.00 | 1.80 | 1.89 | 1.75 | 1.50 | 1.86 | 1.89 |
| Fault tree analysis (FTA) | 1.91 | 1.67 | 1.75 | 2.40 | 1.95 | 1.91 | 1.82 | 2.18 | 1.88 |
| Failure mode effect analysis (FMEA) | 1.91 | 1.63 | 2.00 | 2.29 | 1.88 | 1.85 | 1.67 | 2.17 | 1.88 |
| Design for assembly (DFA) | 1.76 | 2.00 | 2.00 | 2.17 | 1.63 | 1.50 | 1.73 | 2.00 | 1.78 |
| Design for manufacturing (DFM) | 1.79 | 2.00 | 2.00 | 2.17 | 1.63 | 1.73 | 1.73 | 2.00 | 1.88 |
| Life-cycle assessment (LCA) | 1.68 | 1.33 | 2.00 | 2.17 | 1.82 | 1.48 | 1.64 | 1.57 | 1.80 |
| Entropy assessment | 1.57 | — | — | 3.00 | 1.00 | — | 2.00 | 1.00 | 1.67 |
| Benchmarking 2 | 2.02 | 2.00 | 1.93 | 2.20 | 1.90 | 1.82 | 1.86 | 2.27 | 1.95 |
| 2D CAD system | 2.53 | 2.25 | 2.64 | 2.57 | 2.64 | 2.57 | 2.53 | 2.43 | 2.59 |
| 3D CAD system | 2.37 | 2.00 | 2.61 | 2.45 | 2.41 | 2.27 | 2.50 | 2.54 | 2.52 |
| PDM (Product Data Management) system | 2.03 | 2.00 | 2.09 | 1.92 | 2.30 | 1.78 | 2.31 | 2.17 | 2.30 |
| Numerical analysis / Simulation | 2.34 | 2.30 | 2.14 | 2.50 | 2.42 | 2.37 | 2.47 | 2.40 | 2.45 |
| Commercial CAE software | 2.33 | 2.33 | 2.25 | 2.50 | 2.23 | 2.33 | 2.56 | 2.27 | 2.50 |
| Originally developed simulation software | 2.19 | 2.40 | 2.14 | 2.54 | 2.24 | 2.14 | 2.20 | 2.00 | 2.43 |
| Other kinds of numerical analysis software | 3.00 | — | — | — | — | 3.00 | — | — | — |
| Optimal design based on mathematical programming | 1.76 | 2.00 | 1.67 | 2.00 | 1.50 | 1.91 | 2.00 | 1.71 | 1.83 |
| Commercial software for optimal design | 1.97 | 2.00 | 2.25 | 2.40 | 1.50 | 2.13 | 1.83 | 1.71 | 2.00 |
| Originally developed software for optimal design | 2.10 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 1.60 | 2.00 | 2.50 |
| Other kinds of software for optimal design | 2.00 | 2.00 | — | — | — | — | — | — | — |
| Rapid prototyping | 2.28 | 1.67 | 1.90 | 2.18 | 2.38 | 2.25 | 2.50 | 2.45 | 2.55 |
| Design of experiment | 1.93 | 2.20 | 2.24 | 2.27 | 2.00 | 1.74 | 2.06 | 2.25 | 1.94 |
| Total quality control / Total quality management (TQC / TQM) | 1.91 | 2.07 | 1.84 | 1.94 | 2.00 | 1.76 | 2.06 | 2.00 | 2.05 |
| Statistical quality control | 1.97 | 2.29 | 1.95 | 2.20 | 2.05 | 1.75 | 2.07 | 1.92 | 2.16 |
| Statistical quality management | 1.90 | 2.10 | 2.00 | 2.18 | 1.73 | 1.65 | 1.90 | 1.80 | 2.00 |
| Activity-based cost accounting | 1.62 | — | 2.50 | 2.00 | 1.00 | 1.25 | 1.60 | 1.75 | 2.00 |
| Literature survey | 2.14 | 2.09 | 2.33 | 2.19 | 2.22 | 2.08 | 2.16 | 1.93 | 2.24 |
| Patent retrieval | 2.32 | 2.27 | 2.41 | 2.41 | 2.26 | 2.15 | 2.62 | 2.00 | 2.52 |
| Design catalog retrieval | 1.86 | 1.88 | 1.82 | 2.10 | 1.79 | 1.91 | 1.50 | 1.88 | 1.69 |

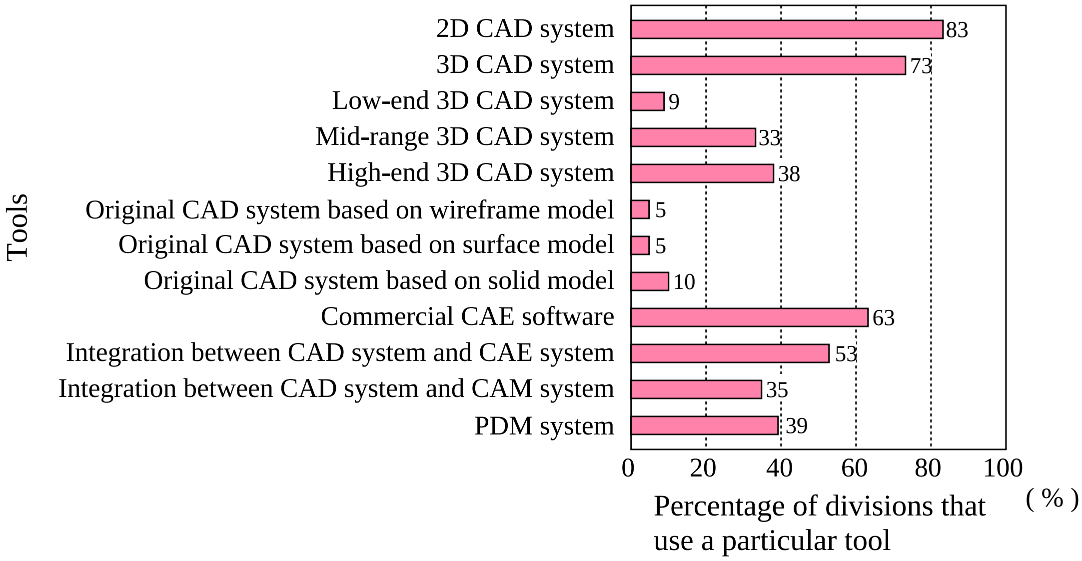


Figure 7　Utilization of digital engineering tools

Table 3 shows how utilization of tools and methods, which is shown in Figure 3, is different among types of industry. It is remarkable that the utilization of tools and methods in automotive industry overwhelmed other types of industry in Japan. And, information equipments industry is the second in high utilization. These may be caused by the severe competition and the scale of business in the global marketplace.

Table 4 shows how much a particular method or tool is contributed to product development in their utilization and differences in such degree across types of industry. The number in each cell of the table is an average of points given 3 for 'it is very effective', 2 for 'it is effective' and 1 for 'it is less effective' across all answers that state its utilization. The result shown in the table reveals the following points:

- Methods for product planning and conceptual design are recognized to be effective in automotive industry, electric and electronic consumer appliances.
- Fault tree analysis (FTA) and design for assembly (DFA) are recognized to be effective in machine components.

Figure 7 shows utilization rates of various digital engineering tools developed under information technology such as CAD, CAM and CAE systems. Table 5 shows their differences among types of industry. The former result and results gotten from related questionnaire items summarizes as follows:

- Several kinds of CAD systems are used at the same time. Major reasons are the replacement from old one to new one, the requirement for simultaneously supporting different types of engineering activities, etc.
- The problems involved in information systems are that learning on how to use them takes a lot of time, that initial cost for introduction is so high, and that it is expensive to introduce the necessary number of software systems and related hardware.

Further, the differences among types of industry are summarized as follows:

- Automotive industry and electric and electronic consumer appliances industry have already well shifted to three-dimensional CAD systems.
- Industrial equipments and machinery industry and information equipments industry are dependent on two-dimensional CAD systems more than the others. They may be used as substitution of drawing.

Table 5 Utilization of digital engineering tools in different types of industry

| Digital engineering tools \ Types of industry (Utilization (%)) | Total | Raw material for industry | Electronic parts | Machine components | Industrial equipments and machinery | Industrial facilities | Information equipments | Automotive | Electric and electronic consumer appliances |
|---|---|---|---|---|---|---|---|---|---|
| 2D CAD system | 83 | 56 | 68 | 100 | 90 | 95 | 94 | 66 | 73 |
| 3D CAD system | 73 | 52 | 50 | 93 | 80 | 73 | 77 | 100 | 91 |
| Low-end 3D CAD system | 9 | 16 | 14 | 0 | 5 | 7 | 7 | 0 | 9 |
| Mid-range 3D CAD system | 33 | 32 | 14 | 53 | 35 | 41 | 33 | 0 | 41 |
| High-end 3D CAD system | 38 | 32 | 23 | 40 | 50 | 32 | 33 | 83 | 68 |
| Original CAD system based on wireframe model | 5 | 12 | 0 | 7 | 0 | 5 | 0 | 0 | 0 |
| Original CAD system based on surface model | 5 | 16 | 0 | 7 | 0 | 7 | 0 | 0 | 0 |
| Original CAD system based on solid model | 10 | 12 | 18 | 13 | 15 | 8 | 0 | 0 | 0 |
| Commercial CAE software | 63 | 52 | 5 | 74 | 75 | 68 | 60 | 100 | 63 |
| Integration between CAD system and CAE system | 53 | 52 | 45 | 73 | 65 | 42 | 60 | 100 | 77 |
| Integration between CAD system and CAM system | 35 | 16 | 32 | 47 | 30 | 31 | 47 | 83 | 55 |
| PDM system | 39 | 12 | 41 | 40 | 30 | 46 | 47 | 100 | 33 |

- Automotive industry much depends on high-end CAD systems and advances in integration between CAD systems and CAE systems.

These points well correspond to the situation that automotive industry leads the introduction of high-performance CAD and CAE systems under the characteristics of their products. However, even though some tools and methods are easy and inexpensive to introduce, they are not utilized in several types of industry. This contrast means that it is required to objectively discuss what is the best model for utilization in each type of industry, by the scale of business, etc.

## 5 Concluding Remarks

This paper reported a questionnaire survey on utilization of tools and methods for product development and its analysis. The gotten knowledge is summarized as follows:

- Regarding individual tools and methods, methods for communication and tools the mechanisms and effects of which are obvious are well recognized on their usefulness, and are getting to be introduced according to their awareness.
- Some tools and methods are not recognized even as their names, except the situation of automotive industry.
- While it can be confirmed that any organizational activity is effective for promoting utilization of tools and methods, more utilization requires any systematic promotion activity with a global view on the overall process of product development

While several types of biases must be involved in the result, the survey brought some evidences on the roles and characteristics of respective tools and methods for enhancing the performance of product development. Further, international comparison between Japan and Western countries indicated the last point of the above. The gotten insights are expected to facilitate their effective and rational promotion toward enhancing product development performance in the near future. Since various factors are related to product development and its overall circumstance is always transforming, this kind of questionnaire survey and discussion are expected to be repeated periodically on different situations under different viewpoints.

## References


[1] Fujita, K., "Essay on Strategic Product Development and Design Engineering," *Proceedings of JSME 12th Design Engineering and Systems Conference*, No. 02-31, (2002), pp. 214-217, (*In Japanese*).

[2] Araujo, C. S., Benedetto-Neto, H., Campello, A. C., Segre, F. M. and Wright, I. C., "The Utilization of Product Development Methods: a Survey of UK Industry," *Journal of Engineering Design*, Vol. 7, No. 3, (1996), pp. 265-277.

[3] Whybrew, K., Shaw, A., Aitchison, D. and Raine, J., "Use of Design Tools and Methodologies for Rapid Product Development in the New Zealand Manufacturing Industry," *Proceedings of 13th International Conference on Engineering Design — ICED 01, Unified Engineering Design — Building A Partnership between Research and Industry*, (2001), pp. 27-34.

[4] Janhager, J., Persson, S. and Warell, A., "Survey on Product Development Methods, Design Competencies, and Communication in Swedish Industry," *Proceedings of Fourth International Symposium on Tools and Methods of Competitive Engineering* (*TMCE2002*), (2002), pp. 189-199.

[5] Ishii, K., "Life-Cycle Engineering Design," *Transactions of the ASME, Special 50th Anniversary Design Issue*, Vol. 117, (1995), pp. 42-47.



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