Chapter 4

Supplemental methods for DTCN methodology

Abstract

This chapter describes techniques to make the DTCN methodology more readily usable.
These techniques are also frequently used in the DTC method.

The following sections describe relevant additional techniques required to use the DTCN/DTC methods:
①NM Method

This method, devised by Masakazu Nakayama, accelerates the creation of ideas after key words have been identified. This method, with some explanatory figures, is added to this book with his permission as appendix A.

② WBS Method

Because the WBS (Work Breakdown Structure) is expressed in several ways, the interpretation of the method has become confused: some users interpret the method on the basis of MIL-STD-881A, whereas others interpret it from the meaning of the name alone. To avoid confusion, one conclusion by the author, the Japan Defense Agency, and the National Space Development Agency in Japan was made in the Aerospace Engineering Handbook of Japan published in September, 1992. Subsection 4.2 gives details.

③ Combination of WBS (MIL-STD-881A style) and PMD

This method is effective in the early stage of design work to convert system subjects to practical subjects. It is used to put design jobs together in the early stage of designing when the DTC method is used.
Although the WBS (MIL-STD-881A style) and PMD belong to WBS in the wider sense, their practical relation has not been fully understood. Subsection 4.1 will explain how to use them properly. Subsection 4.3 will explain how to combine them using an example from the early stages of designing.

④Structured evaluation technique for pre-evaluation from a rational perspective

This method puts into practice the structured evaluation technique devised by the author, and the related method devised by Fasal, T. Fujita, and Klee, et al. Subsection 4.4 will describe the method.

Chapter 4

Supplimental methods for DTCN Methodology

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4.1 WBS Method (Re-definition)

4.1.1 Introduction

This chapter re-defines the Work Breakdown Structure (WBS) on the basis of its original specification, and introduces a method for quickly making several kinds of WBS using cards.

This chapter supplements section A9.2.4 "Work Breakdown Structure" in Chapter A9, "Developmental Project Management," of the Aerospace Engineering Handbook published in September 1992.

4.1.2 What is WBS?

WBS is the abbreviation for Work Breakdown Structure. This term is defined in the military specification, MIL-STD-881A[1], of the Secretary of Defense of the United States. People in general do not know of the existence of the specification, and so interpret its meaning from the name. This causes confusion about its meaning, both in the United States and in Japan, between those who interpret WBS from the military specification and those who interpret it from the name. In spite of this, it has been demonstrated from the experiences of its users that the concept of WBS is useful and efficient for itemizing and relating work and jobs, and is suitable for clarifying complicated subjects, irrespective of which interpretation the users take. Therefore, this chapter interprets and defines WBS in the wider sense* to expand the fields where the WBS method can be used effectively.

* Quoted from Section A9.2.4 "Developmental Project Management" (p.273-275) of the Aerospace Engineering Handbook of Japan (Maruzen), New edition, 1992 [2]

4.1.3 WBS in the wider sense

MIL-STD-881A explains the concept of WBS in military specifications. The WBS method itemizes and defines all the factors constituting a system, including hardware, service, and data, at various levels of the whole system (uppermost), sub-systems, and components. It has been widely used as a tool in developmental project management, budget control, and contracts.

Figure 4.1-1 shows an example of WBS in an airplane system.

Notes on Figure 4.1-1:

To make a horizontal WBS as shown in Figure 4.1-1 without “missing items”, it is necessary to first make it vertically as shown in Figures 4.1-2 and 4.1-3, and then convert it to a horizontal view. The vertical view eliminates vertically “missing items” or “faulty items” in the vertical purposes and measures sequence by the principles of PMD explained in subsection 3.2. The horizontal view allows us to horizontally detect “missing items” or “faulty items” because horizontal comparative recognition is easy to do with our horizontally arranged eyes. (This is called matrix pattern recognition without “missing items” or “faulty items”). Thus, “missing items” or “faulty items” can be eliminated from the final horizontal WBS.

More details are given in Episode 11.

The objectives of WBS include:

- to show the parent-child relation and classification of jobs without “missing items”; and
- to define the functions of the jobs without “missing items”.

When the concept of WBS is enlarged, WBS can be used to:

- properly define the relation between the purposes and measures of the work; and
- prevent “missing items” in the order and items of the work.

Fig.4.1-3A and Fig.4.1-3B show the examples of WBS applications.

Figure 4.1-4 shows the various patterns and uses of WBS in the wider sense.

4.1.4 How to prepare a parent-child-style WBS (WBS method)

Two possible ways to make a WBS are introduced.

(1) Method using the FBS technique

This method was explained in the seven basic methods of DTCN in Chapter 2.

(2) Method to prepare a provisional WBS using cards (can be used by one or more people)

① First, decide on a theme as the uppermost level-1 theme, or a subject (When it is difficult to decide on a theme, follow the "Theme key word method"). The subject name should suggest its contents (As a Japanese proverb says, “name and nature often agree”). Stick the determined subject on the upper left side of a large piece of paper with mending tape.

② On the paper, list the components of the subject using as many nouns (or nouns with minimal adjectives) as possible, getting input from all participants.

③ Cut the paper into cards so that each card contains one noun (It is also possible to write nouns on "POST-ITs" to avoid this procedure)

④ Select the cards likely to be classified as Level 2 on the basis of the concept shown in Figure 4.1-2, and arrange them at the Level 2 position on a large piece of paper.

⑤ Arrange the remaining cards so that a parent-child-type WBS can be obtained as shown in Figure 4.1-3. When there is a "grandchild" card, arrange it as shown in the right figure of Figure 4.1-3.

⑥ In cases such as in ⑤, arranging the items at Level 3 so that they can be horizontally evaluated with those at Level 2 will reveal omitted items at Levels 2 and 3.

⑦ Add cards to the omitted positions

⑧ When the WBS pattern is complete, fix the cards on the large piece of paper with transparent mending tape and draw lines to connect the items as shown in the right figure of Figure 4.1-3.

⑨ Adjust the completed WBS with the participants, if necessary.

When the matters within the scope in which the WBS is prepared are disputable, first make a PMD among participants. Then, after the domain of consensus has been identified by the PMD, make the WBS as above.

4.1.5 Software to input the above results (this product was prepared by the author)

(1) The parent-children relations in the WBS obtained in the above are numbered on the input screen as shown in Figure 4.1-5.

(2) The file is saved to disk after the input is completed.

(3) The software product automatically makes a list indicating the parent-child relations* as shown in the left side of Figure 4.1-6.

* This is called a GOZINTA table (meaning "GOES INTO" table)

(4) This table makes subsequent management tasks very easy.

Tables 4.1-7 and 4.1-8 are the input and list displays of the software product that was made for the FBS diagram.

4.1.6 Discussion

There is the term WBS (the general meaning of work breakdown structure) and its narrow definition by MIL-STD-881A. Because its definition as a whole has been ambiguous and its relation with FTS (Function Tree Structure) is unclear, even in the case of MIL-STD-881A style WBS, instructions of how to make a WBS have been inadequate.

This book addresses this problem in the following ways:

(1) The narrow and wide senses of WBS are defined on the basis of the way of thinking for the DTCN method and related techniques.

(2) The steps and method to quickly make and adjust provisional WBSs are based on the narrow sense of WBS.

(3) Chapter 3 shows that, to prepare more appropriate and complete WBSs, the concepts and procedures of the 7 basic methods of the DTCN methodology should be used according to each purpose of WBS.

<References>

[1] Department of Defense, MIL-STD-881A, Work Breakdown Structure for Defense Material Items

[2] Aerospace Association of Japan, Aerospace Engineering Handbook (Maruzen 1992), pp.273-275

[3] Defense System Management College, Systems Engineering Management Guide (1996), p.6-2-3

ISBN 0-941243-00-1

Fig.4.1-1 Examples of WBS (Aircraft system) Reference: Aerospace Engineering Handbook (Maruzen Publishing Co.1992) page 348.

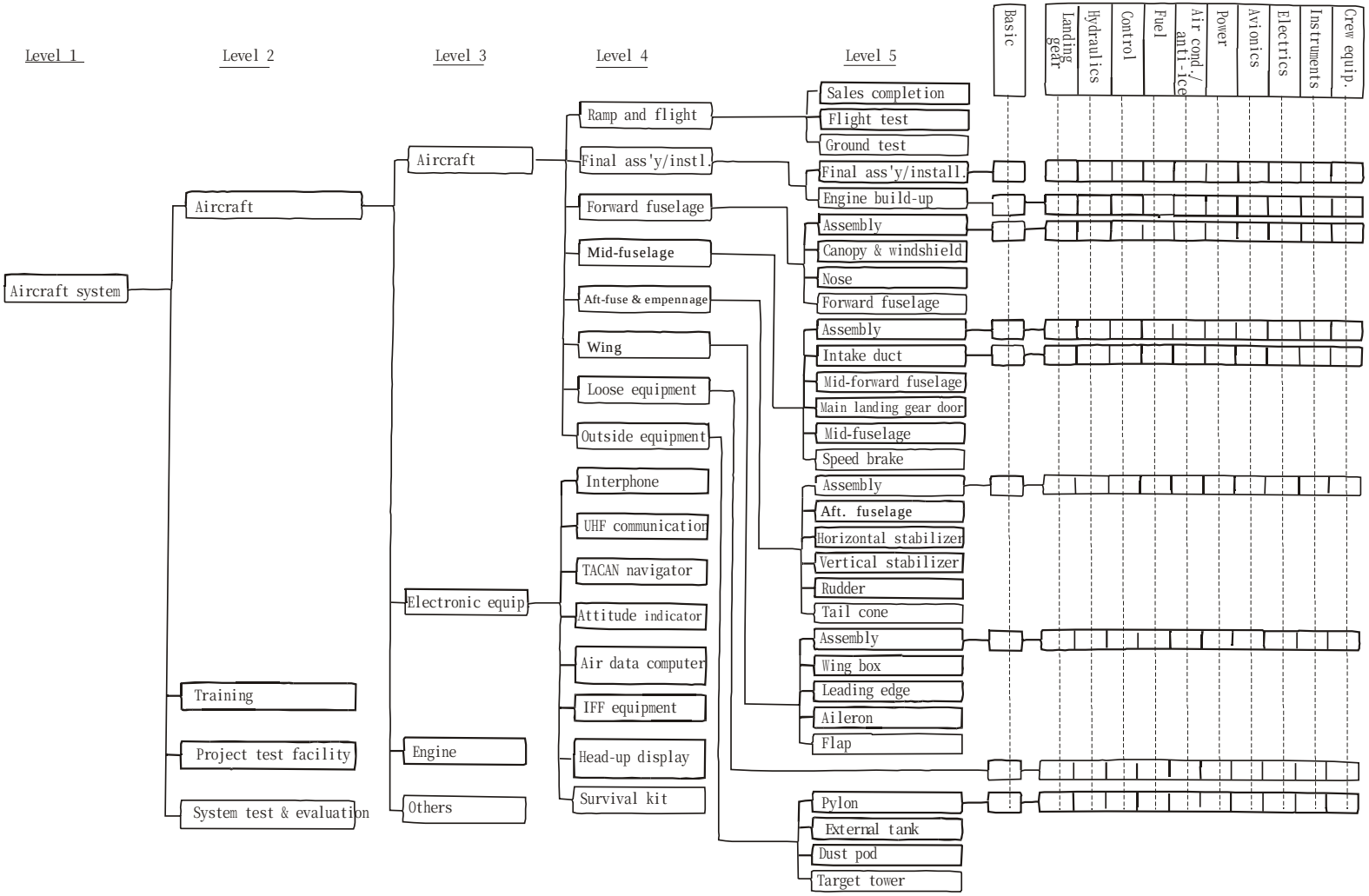


Fig. 4.1-2 WBS (MIL-SDT-881A style example)

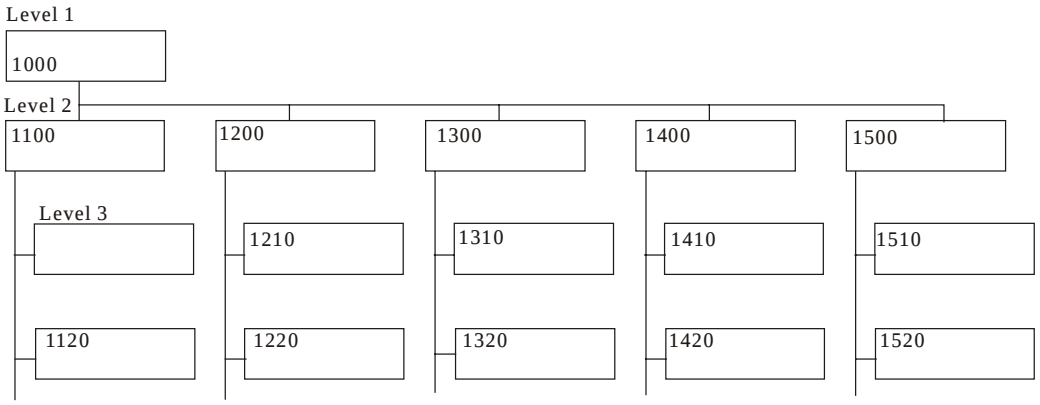


Fig.4.1-3 How to show the relationship of parents and children when using the format of WBS

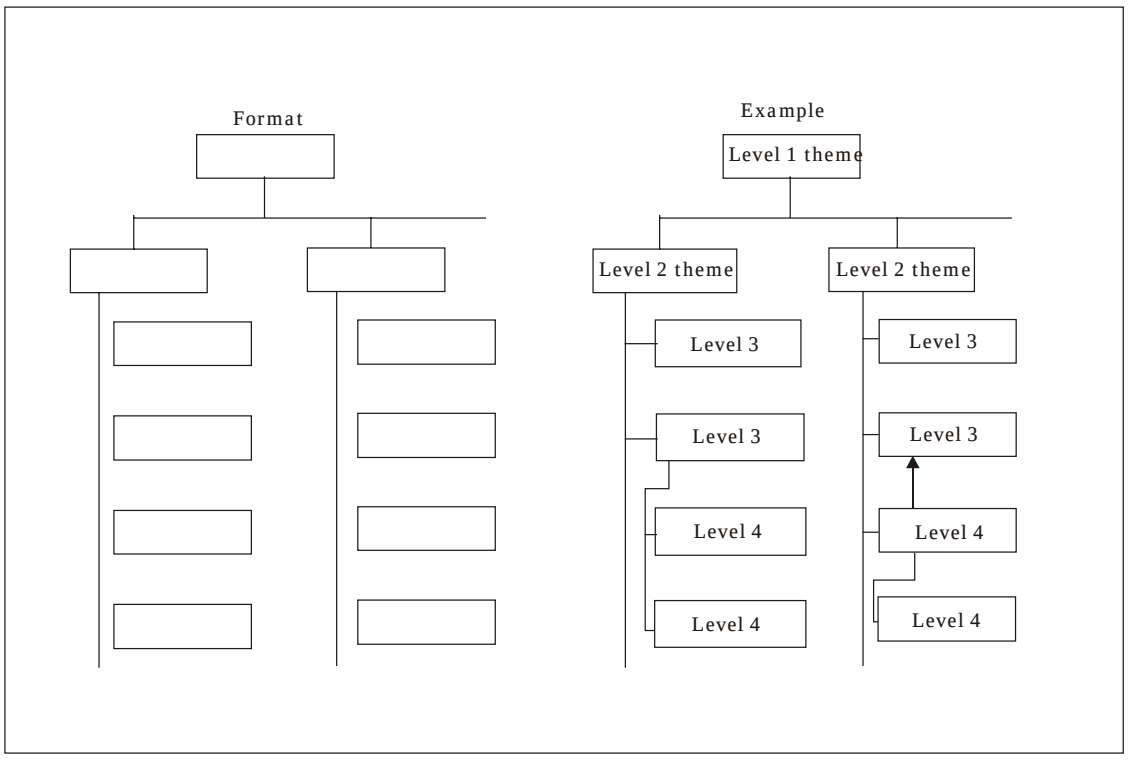


Fig.4.3-3A

ＯＢＳ(Organization Breakdown Structure)×
Activity WBS Matrix

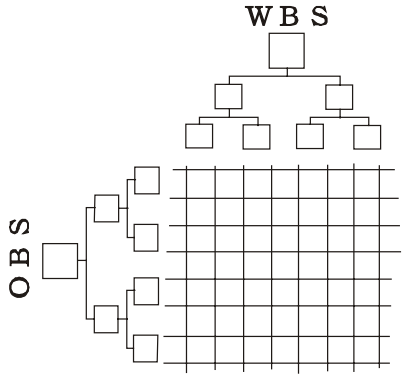


Fig.4.3-3B
Combined Type

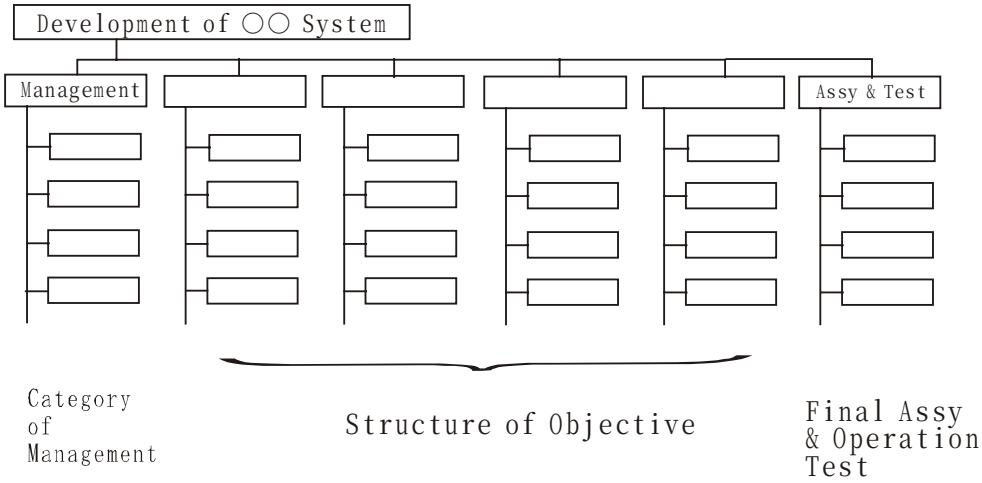


Fig. 4.1-4 Broad meaning of WBS pattern

Reference: Aerospace Hand Book (Maruzen,1992, p274)

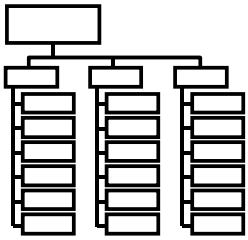
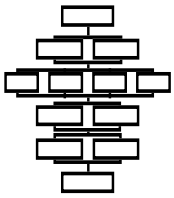
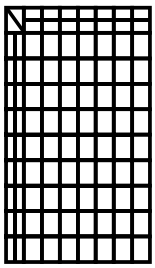
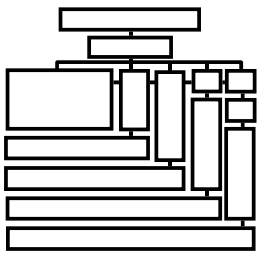
Style	Purpose of WBS	Style of WBS	How to make it
Parents And Children Style	1. To clarify up the relationship between parents and children 2. To define the development activities 3. To show the organization		1. By MIL-STD-881A 2. To pick up and arrange faultlessly in a relationship of parent and child 3. By FBS technique
Purpose-Measure Style	1. To have consensus and get same vector to make decision 2. To examine the relationship of development test 3. To find out where to start	Purpose ↑ ↓ Measure 	By PMD method
Procedural WBS Style	1. To clarify the phased step 2. To clarify the relationship between input and output 3. To allocate the decision-making process in which we decide when and by what evaluation standard is used in logical event sequence	↓ Procedure 	By steplist management method
	1. To proceed with parallel Improvement from present status		By 3-5 phase improvement method

Fig.4.1-5 Image of computer software for WBS making

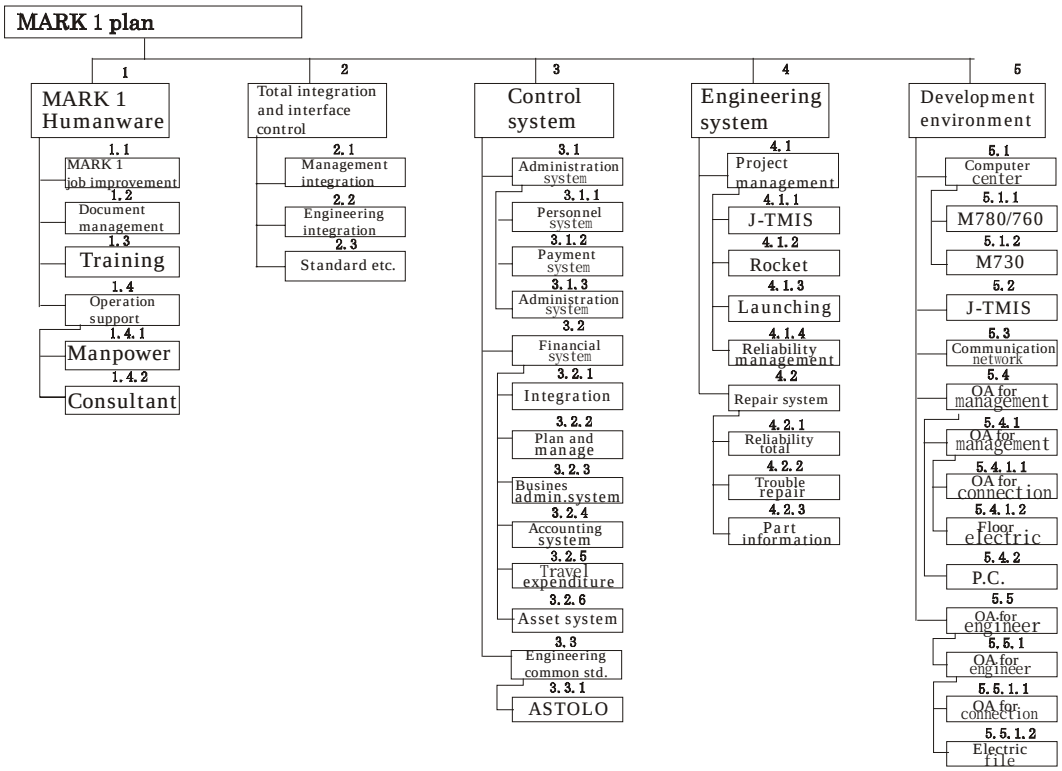


Fig. 4.1-6 List of contents of Fig.14-5 by software

NO.	Parent and children					WBS NO.	CL	Item name	Assignment	GO-AHEAD	Conditions	Work contents	Dated required	Estimated comp. date
1	X					1		MARK-Humanware						
2		X				1.1		MARK-1 Job improvement						
3		X				1.2		Document management						
4		X				1.3		Training						
5		X				1.4		Operation support						
6			X			1.4.1		Manpower						
7			X			1.4.2		Consultant						
8	X					2		Total integration and interface control						
9		X				2.1		Management integration						
10		X				2.2		Engineering integration						
11		X				2.3		Standard etc.						
12	X					3		Control system						
13		X				3.1		Administration system						
14			X			3.1.1		Personnel system						
15			X			3.1.2		Payment system						
16			X			3.1.3		Administration system						
17		X				3.2		Financial system						
18			X			3.2.1		Integration						
19			X			3.2.2		Plan and manage						
20			X			3.2.3		Business administration system						
21			X			3.2.4		Accounting system						
22			X			3.2.5		Travel expenditure						
23			X			3.2.6		Asset system						
24		X				3.3		Engineering common standard						
25			X			3.3.1		ASTOLO						

Fig. 4-1-7 Image of software for FBS

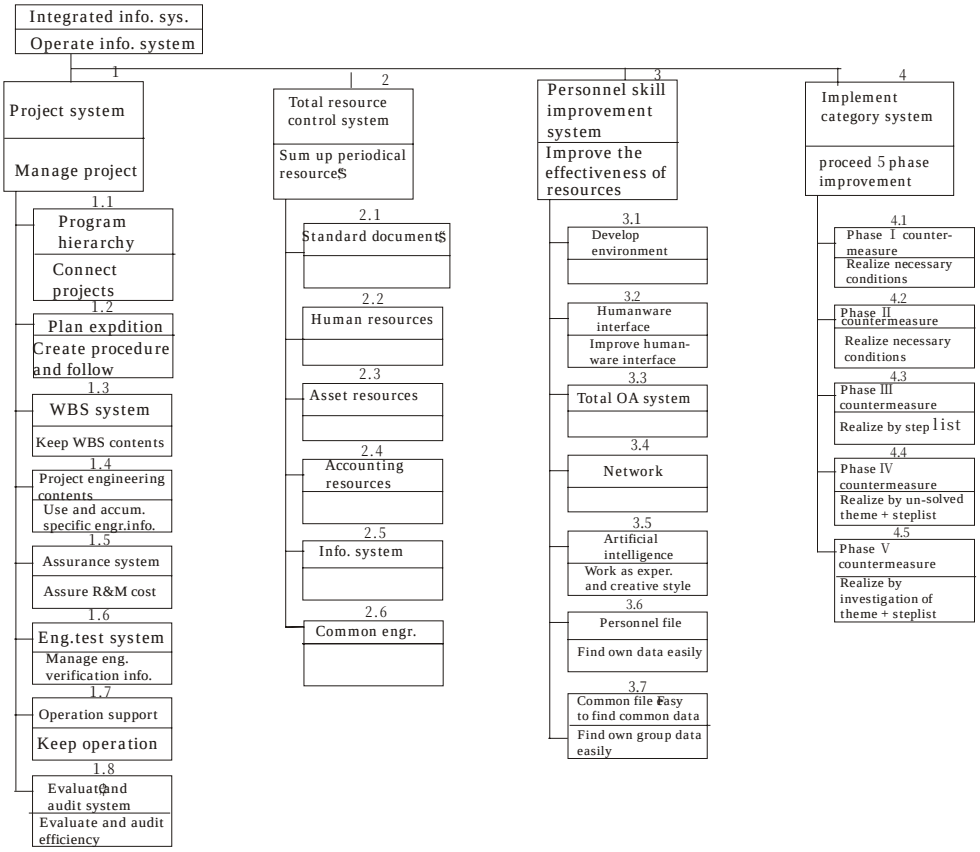


Fig.4.1-8 Contents of Fig.4.1-7 automatically listed by software

FBS parent children relationship list

Theme： Integrated information system(Operate information system)

NO.	Rellationship of parent and children						WBS NO.	CL	Item name	Assign-ment	GO-A-HEAD	Conditions	Work contents	Date required	Estimated comp. date
1	X						1		Project system Manage project						
2		X					1.1		Program hierarchy Connect the project						
3		X					1.2		Plan expedition Create procedure and follow						
4		X					1.3		WBS system Keep WBS contents						
5		X					1.4		Project engineering contents Use and accumulate specific engr.info.						
6		X					1.5		Assurance system Assure R/M cost						
7		X					1.6		Engineering test system Manage engineering verification info.						
8		X					1.7		Operation support Keep operation						
9		X					1.8		Evaluation and audit system Evaluate and audit efficiency						
10	X						2		Total resource control system Sum up periodical resources						
11		X					2.1		Standard document						
12		X					2.2		Human resources						

Episode 11. Effects of two styles of WBS, lateral sentence-connecting and vertical parent-child, on the balance of contents and the prevention of "missing items" or "faulty items"

See Figure 1 in Episode 11.

(A) on the left was prepared by a company as the WBS of an XXX software structure. It was not well itemized and needed a revision to make it clearer; however, it was not clear how to revise it.

The author advised the company to rearrange the WBS as shown in (B) to find "missing items" or "unbalanced items." (B) shows the rearrangement of (A) without any change in the contents.

(B) demonstrates what we could not see in (A). That is, (B) readily shows the unbalance in the parent-child relations, which was not clearly found in (A). For example, it can easily be detected that the position of "6.3 Project Management" under "6. Technical Management System" is wrong.

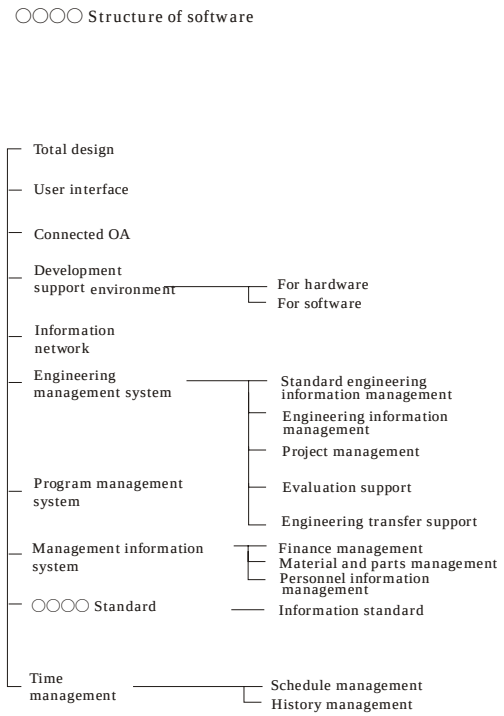
The above comparison shows that the arrangement in (B) clarifies the parent-child and horizontal relations. This is probably because our eyes are horizontally arranged.

Therefore, the parent-child-type WBS should first be prepared, as shown in (B), and then, if necessary, re-arranged to the horizontal-connection-type of (A) so that it can easily be written out using a word processor.

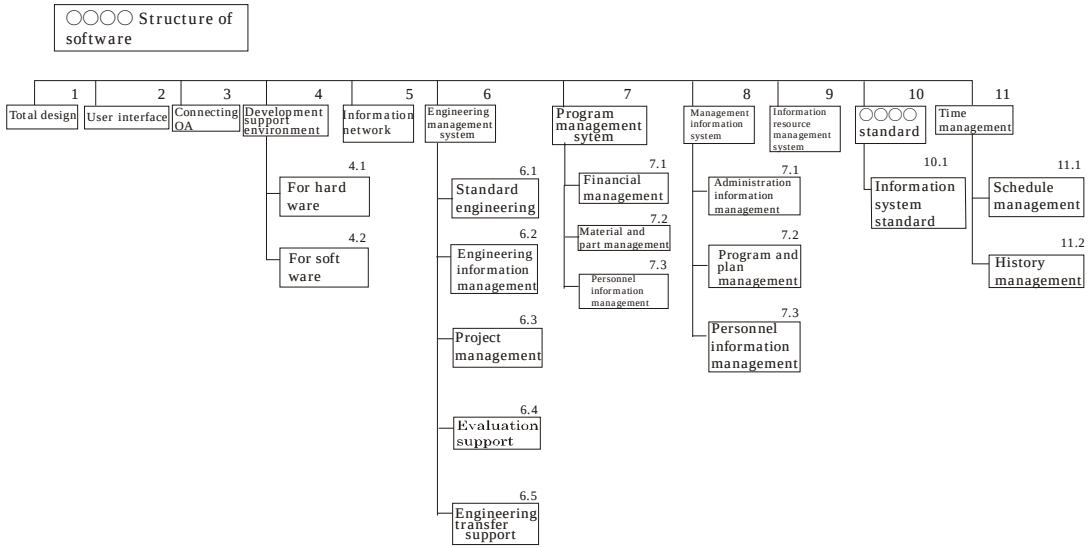
If possible, however, it would be better to leave it unchanged, as shown in (B), because the parent-child-type produces far fewer mistakes, is easily understood, and is useful for grasping and adjusting the total image of WBS.

Episode 11 Fig.1

(A) Style WBS



(B) Style WBS



Method to look at faultless WBS

Our eyes are set horizontally.
If we compare style (A) WBS and style (B) WBS , (B) style is superior because it is easier to check whether WBS components are missing, and whether categolizing level of the components are appropriate or not. This is because our eyes are set horizontally.

Therefore, we must first to make a (B) style WBS to check for missing WBS components and to see whether WBS components are properly leveled.

After identifying a properly arranged WBS using style (B) WBS, then you can use the style (A) WBS expression.

4.2 WBS in Moebius style to effectively and efficiently allocate design work in the beginning stages (Moebius strip-style WBS)

4.2.1 Introduction

This section explains a Moebius strip-style WBS, which is a combination of the conventional MIL-STD-881A-style WBS and the PMD method. It is effective for allocating the design work in the beginning stage of design.

This is called a Moebius strip-style WBS because its form resembles a Moebius strip.
It is impossible to escape from the true Moebius strip. Our thinking, however, can escape from the strip because rotating the strip a few times will reveal different aspects of the subjects in order to solve the problem in a very smart style..

4.2.2 What is a Moebius strip-style WBS ?

Our daily experiences indicate that WBS is effective for allocating tasks without “missing items” because it itemizes the contents of the tasks. This section explains a method developed and put into practice by Tateaki Nagashima of Fuji Heavy Ind. Co. and the author by combining the WBS and PMD methods. .

This method is designed to combine, deploy, and structure the methods effectively, efficiently, and spatially in the early stages of design and to use them for extracting work items without “missing items”, allocating examination of the work items, and expediting the whole design work. This method can be used not only in the early stages of design and planning, but also in the early stages of a project, which is complicated, to find the starting point and its process. The combined pattern of the WBS based on the MIL-STD-881A-style WBS and PMD method is tentatively called "Moebius-style WBS" to distinguish it from the conventional WBS (*).

* A conventional WBS is prepared by the WBS method as shown in subsection 4.1.

4.2.3 Overall flow of the Moebius strip-style WBS

Figure 4.2-1 shows the overall flow of the Moebius-style WBS. The purpose of this overall flow is to allocate the work for design without “missing items”. Figure 4.2 shows the flow from the upper system subject to intended results into the lowest level of the Figure.

In the flow table, the frame containing "Work items to be attended" and the arrows of (a), (b), and (c) entering and leaving this frame indicate the work flow of the interface control between WBSs.

The following subsection explains how to prepare the Moebius-style WBS using the examples from Figures 4.2 to 4.8.

4.2.4 How to spread a Moebius strip-style WBS

(The following explanation uses the WBS numbers in the WBS in each figure)

(1) WBS of development (Levels 1-3) (Figure 4.2-2)

The components and structure of the developmental WBS depend on the components and structure of the answers to the following key questions:

① What items of component or structure are necessary to construct the product or system?

WBS 100000 (110000 - 140000) (Vertical column on the left of Figure 4.2-2)

② What items of design work are required to obtain each of the components without any “missing items”?

WBS 200000 (210000 - 230000) - 500000 (from the second to fifth column in Figure 4.2-2)

③ What items of a phased step are used to examine design work? (Phased steps)

WBS 210000-I, 210000-II, 210000-III, 210000-IV, 210000-V (details of the second column of Figure 4.2-2)

④ What items of engineering data are used to control the design work and its results (including the control of changes) ?

WBS 600000 (610000-630000) (Sixth column in Figure 4.2-2)

⑤ What items of management are used to control the above components of WBS100000 - WBS600000 (Seventh column in Figure 4.2-2)

(2) Figure 4.2-3: Theme WBS to be examined in each group

When the WBS 21000 for design work in Figure 4.2-2 is used as an example:

① What items of work groups are organized to proceed with the design work ?

WBS 211000 - 217000 (Level 4 in Figure 4.2-3)

② What are the basic tasks for each work group ? (Level 5 in Figure 4.2-3)

Planning group	211100-
Cost estimate group	212100-
Aerodynamics group	213100-
Structural group	214100-
Equipment group	215100-
Electronics group	216100-
Technical material control group	217100-

(3) WBS items to be examined in each group (Example of WBS for the aerodynamics group)

See Figure 4.2-4.

① As for the WBS items to be examined in each group in Figure 4.2-4, the items at Level 5 or lower are developed to those at Level 6.

②The items at Level 6 are expressed by theme name to be examined.

(4) The PM diagram in Figure 4.2-5 (prepared for each theme name to be examined) is an example of the selection between a manual or mechanically boosted rudder. PM is the abbreviation for Purpose and Measure.

Many sub-themes exist in the designing phase and their relations are so complicated in the early stage of design that it is unclear which sub-theme should be examined first. This tendency is more evident when the relations include a so-called chicken-and-egg relationship. In this case, the PM (purpose-measure) diagram in Figure 4.2-5 is useful for clarifying which sub-theme should be examined first .

The PMD method is used to make the PM diagram. . The entrance key word at the bottom of the PM diagram indicates the first sub-sub-theme(s) to be examined. To examine the sub-theme(s) is to clarify the entrance key word(s). Entrance key words are the sub-sub-themes. To allocate the sub-sub-theme(s) will reveal how to proceed with “Entrance of examination work for the sub-theme.”

In this example, the allocated entrance of examination work for the sub-theme is the two expressions at the bottom of Figure 4.2-5, that is:

- the planning group: compare ”the weights and center of gravity” of manual and booster controls;

-the cost group: compare the cost of manual and booster controls:

-the equipment group: create the ideas to be estimated and compared;
- the aerodynamics group: study the conformability of the manual control to the specifications.
- the structural group: examine whether composite materials can be used or not in manual control mechanism

The work traces the PM diagram from the bottom to the top.

(5) Figure 4.2-6 shows the sub-sub-theme WBS for each work group
①The above results are arranged into the form of the examination theme WBS within each group as shown in Figure 4.2-3.. Fig 4.2-6 shows the results.

Arranging the results in the form of the WBS in Fig. 4.2-6 reveals the need to add "the Lifecycle cost estimate by the cost group" and “the creation of the rudder control mechanism to be compared by the equipment group” to the Entrance work, which was not detected in Figure 4.2-5. . Figure 4.2-6 fixes the work allocation of the sub-sub-themes for the working groups in Figure 4.2-2, and shows the complete cycle of examinations and work themes.

We call this type of WBS a Moebius-style WBS because the cycle resembles a Moebius strip. However, the Moebius-style WBS is different from the true Moebius strip because in this style of WBS, making a few rounds in the cycle leads to the exit and the next entrance.

(Note) The WBS in Figure 4.2-6 can also be used to clarify the “input and output” relations between examinations and jobs by connecting the WBS blocks with arrows as shown in Figure 4.2-7.

②To control the progress of jobs, the WBS block is highlighted with colored pencils each time the work of the block has been completed (Usually, the block is highlighted with a yellow fluorescent pen when the work has been started, and with a red fluorescent pen when the work has been completed)

4.2.5 Detailed interface between WBSs

In the practice of developmental work, the main WBS can be prepared using the above method. . However, preparing and maintaining a detailed WBS, or the WBS or PMD for each sub-theme (including interface control) requires a huge amount of work. To overcome this, the formats of the "Work item necessary to take action" and the "Expediting item list necessary to take action" are used as shown in Figures 4.2-8 and 4.2-9, respectively.
When the contents of the required action are so clear that to complete the format of “work item necessary

to take action" is not necessary (*), it is okay to omit the "list for required action" and use the "item list to promote action taken" alone.

* Note: When the contents are clear among the persons concerned as a result of meetings or other activities, it is enough to list the contents in the "expediting item list necessary to take action."

4.2.6 Discussion

(1) The flow table and contents of the Moebius-style WBS reveal the control activities we are always doing in the brain. Figure 4.2-1 shows that there are 5 entrances for (A), (B), (C), (D), and (E) for the control activities. The control activities can be easily managed from any entrance without confusion by recognizing the map of the overall control activities and the 5 entrances.

(2) The way of thinking and method introduced in this section can be used when the themes examined are complicated, such as in the early stages of designing, allocating the jobs to make a production plan, and allocating the theme to be deployed and examined in a subject study, without "missing items" or "wrongly directed work.".

Fig.4.2-1 Flow of Moebius-style WBS (How to organize WBS to proceed with design work effectively and efficiently)

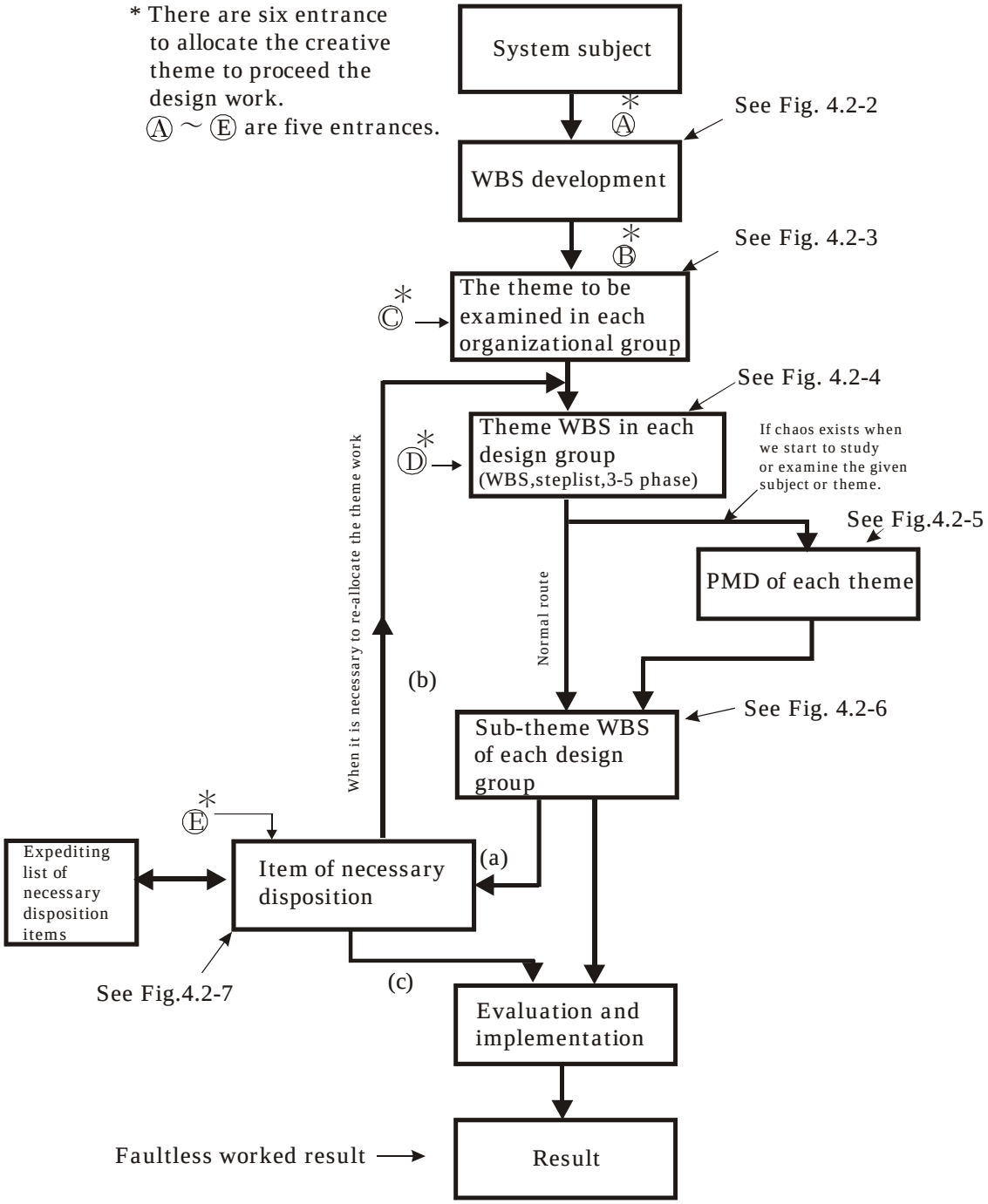


Fig. 4.2-2 WBS of development(Level 1～3)

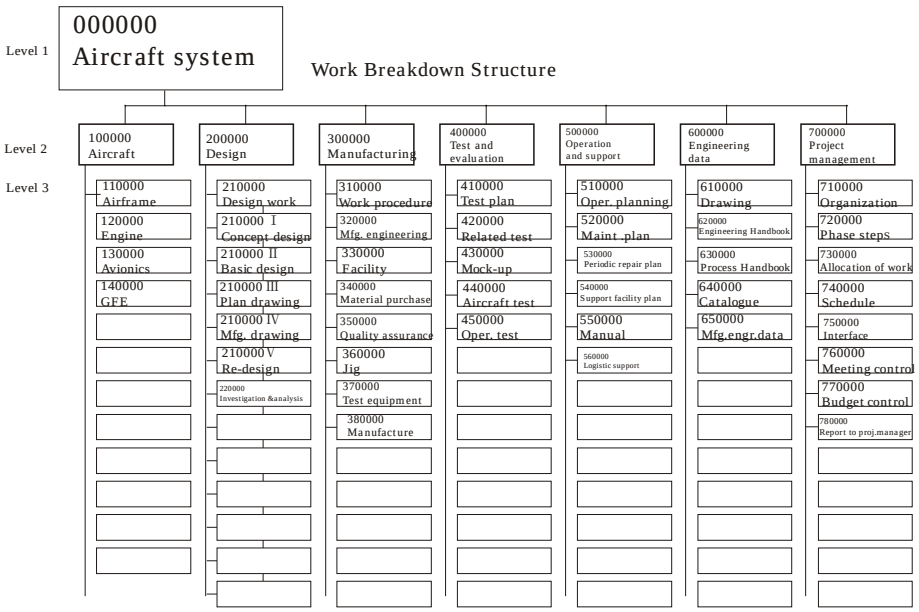


Fig. 4.2-3 Theme WBS to examinate each section

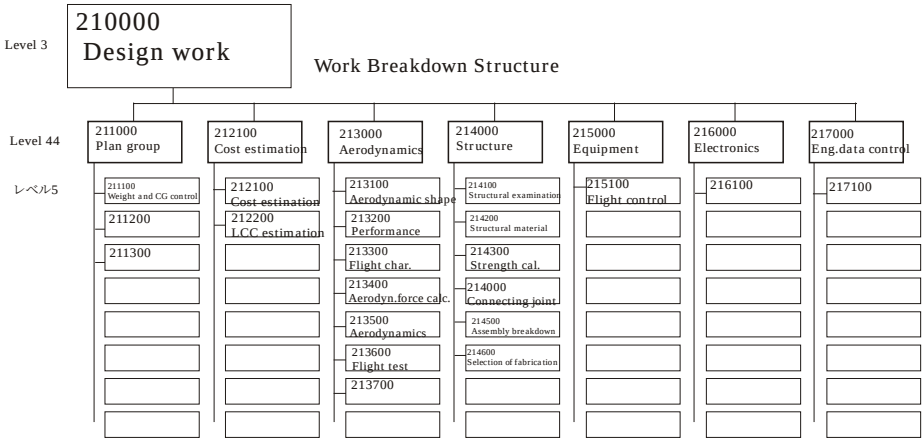


Fig. 4.2-4 Examination/work item WBS within each section

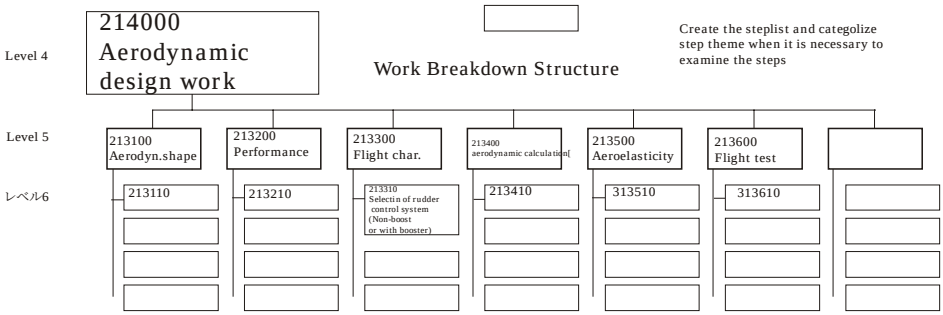


Fig.4.2-5 PM diagram theme: Selection of rudder control system (human power or boosted power)

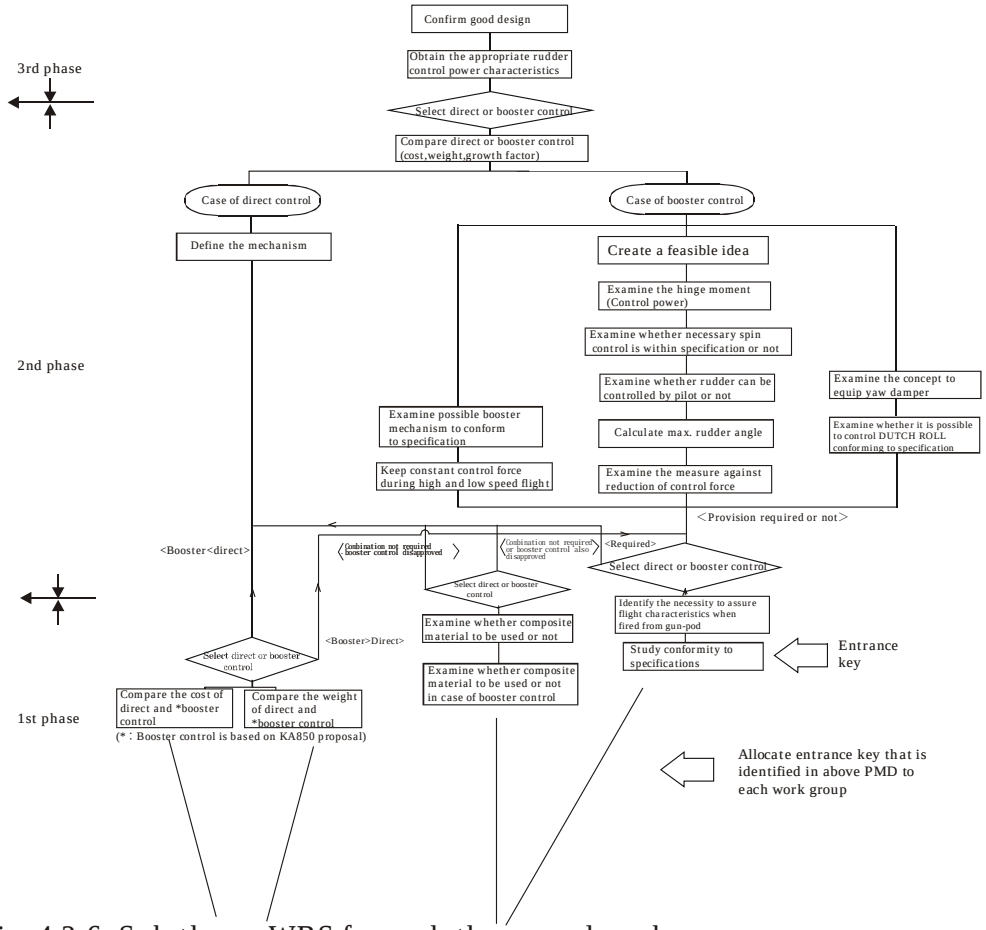


Fig. 4.2-6 Sub-theme WBS for each theme and work group

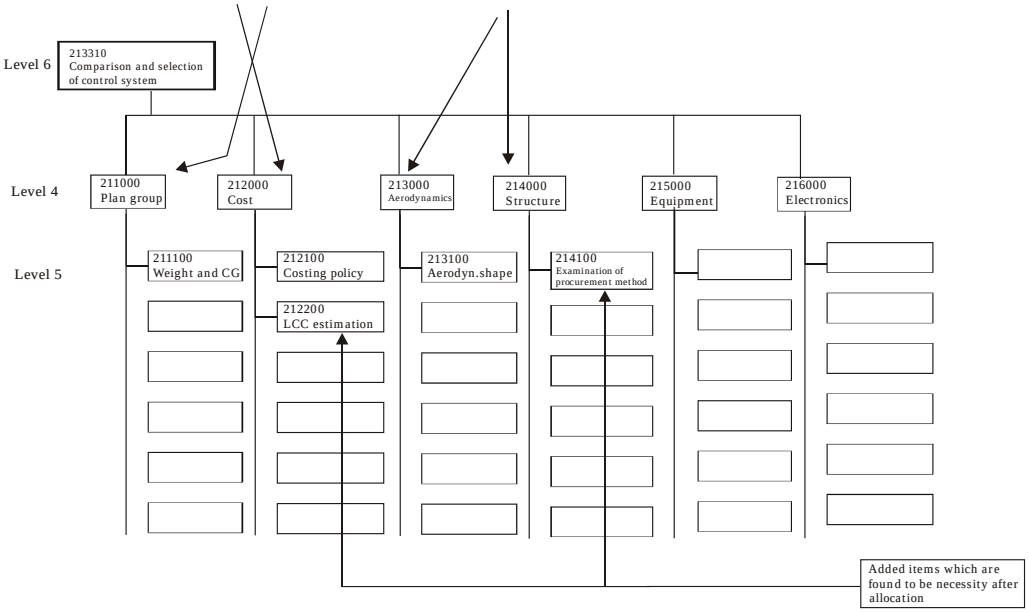


Fig.4.2-7 Example showing work flow relation in WBS

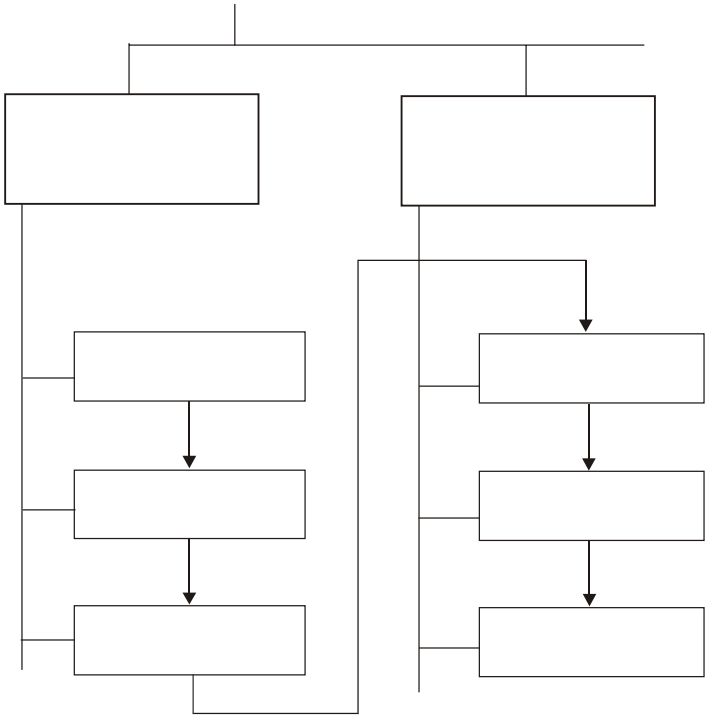


Fig. 4.2-8 Work item necessary to take action

WBS

Item No.	Originator	Group leader	Group	Requested date	Date to be resolved	Estimated completion date	Completion date	Chief or Director
—				／		／	／	

Purpose

Brief description of action item

Brief description of resolving action(draft) Note how to resolve the issue and who would be suitable for resolving it.

Write serial number within each group

Item number X-XXX

Apply document registration No.(e.g. plan group.2,cost group. 3)

2) This format may be used whenever resolving the problem within your own group,or requesting the action from another group.

3) Brief description of action(draft) will be revised,incorporating the negotiated result, and getting the approval of chief or director.

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Fig.4.2-9 Expediting item necessary to take action (Full size format)

Item list to take action

Group

Item No.	Item to be taken action	Requester	Requested date	Estimated period before action finished	Designed date to finish	Scheduled date by negotiation	Moderator	Detail issue item to be negotiated	Notes	Estimated completion date	Actual completion date
	WBS										
	WBS										
	WBS										
	WBS										
	WBS										
	WBS										
	WBS										
	WBS										
	WBS										
	WBS										
	WBS										

4.3 Evaluation and structuring method for pre-evaluation from a rational perspective

4.3.1 Introduction

This section briefly introduces several methods, such as the Scoring method developed by J. Fasal and improved by T. Fujita, Professor of Sangyo Noritsu University; the DARE method developed by A. J. Klee; and the method to combine and select the best structured plans at once, developed by M. Esaki.

4.3.2 What is the pre-evaluation method?

To create a new object requires choosing a policy, plan, design, materials and method, and combining them to create and realize a structured plan. This requires making and comparing several plans, and then deciding which ones should be combined. The plans, however, are compared subjectively because each one is usually uncertain at pre-evaluation. A subjective comparison is likely to provide different viewpoints and lead to misunderstanding, which makes it difficult to reach a conclusion. The following methods are intended to make pre-evaluation possible in a reasonable and quick manner. It is important to remember that the results of the methods have to be checked and adjusted as a whole on the basis of the uppermost purpose.

The methods will be explained in the following order:

(1) Priority Method

(2) Scoring Method (revised) (J. Fasal/T. Fujita)

(3) DARE Method (A. J. Klee)
(4) Considerations in scoring the evaluation
(5) Rules for taking a reasonable majority decision on evaluation plans (M. Esaki)
(6) Method to immediately combine and select the best structuring plans (M. Esaki)
(7) Essentials for evaluation-based decision-making (M. Esaki)

4.3.3 Priority Method

This method is based on the general way of thinking in daily life. For example, when choosing 1 out of 3 plans, the 3 plans are ranked for each evaluation element. The ranking is added or multiplied for each plan, and priority is decided according to the result: top priority is given to the plan with the smallest result (Table 4.3-1). The former is called the addition method, and the latter is called the multiplication method. The example in the table can be easily ranked with the priority method. In this case, it becomes easier to make the final decision if the differences between the plans are quantitatively determined in advance. Our experiences have demonstrated that this method can be used in most cases.

The following methods are used when the priority method cannot provide a decisive conclusion, or when it is necessary to determine weighting coefficients for many evaluation elements.

4.3.4 Scoring Method (revised) (Table 4.3-2)

(1) This method provides the keys to rank and weight evaluation elements.
(2) Even when there are many evaluation elements, it is easy to pick and compare two elements and decide which is more important. When two elements are compared, the more important one is considered to be 1, and the less important one is considered to be 0.
(3) The reasonable consistency in weighting elements can be checked by the evaluation result.

Let's take an example of ranking the evaluation elements in the case of the air intake port of a helicopter turbo shaft engine. When there are 4 evaluation elements, as shown in Table 4.3-2, 6 decisions have to be made ($_4C_2$ times = 4 x 3/2 = 6).

It is important to rank the elements so that their scores in the table are ranked starting from 0, 1, 2, 3, and so on. If not, no consistent algorithm exists in the pair comparison, as shown in Table 4.3-3. Such evaluation elements should be reconsidered, or new pairs of evaluation elements should be added to

maintain the algorithm. In Table 4.3-3, the lack of a consistent algorithm is readily recognized because A is inferior to C in spite of the decisions of A>B and B>C. This is a good example of how clearly the score of the table shows the lack of a consistent algorithm.

Table 4.3-4 shows an example in which the upper and side air inlets of a twin-engine helicopter are compared to determine the remodeling elements of the engine. The weighting coefficients obtained in Table 4.3-2 were used. The comparison yielded the decision that the side inlet was superior to the upper inlet by 2.5 times because the overall score of the former was 95, whereas that of the latter was 38 (95/38=2.5).

4.3.5 DARE (Decision Alternative Ratio Evaluation) Method

This subsection first describes an example that can be generally applied and expanded, and then discusses the applied evaluation example of engine air inlets.

(1) Example of refuge disposal facilities in Table 4.3-5

First, the evaluation elements are randomly arranged in column A. Each element is compared with that over it in terms of importance, and the subjectively determined relative importance ratios are recorded in column B. For example, when the operation cost is 1, the development period is 1.3 times more important than the operation cost, and air pollution is 2.5 times more important than the development period.

In column C, the base value of 1.0 for the bottom element (operation cost) is first recorded. The value is multiplied by the relative importance ratio in the upper element row (development period) in column B, and the result is recorded in the corresponding space of the element in column C.

Column D indicates the ratio of each element to the total of column C when the total is 1.0. Evaluation is made using the ratio of each element as a weighting coefficient, as shown in Table 4.3-4. This procedure is the DARE Method.

Table 4.3-6 shows another application of this method. The table compares the two plans of Table 4.3-4 by the ratio when the score of the side inlet is 1. In this case, the weights in Table 4.3-2 were used. As a result, it was concluded that the side inlet was about 2 times as valuable as the upper inlet. This indicates that there was no difference in the priority between the two tables (Table 4.3-2 and Table 4.3-6) even though the importance ratio was different. That is, the top priority element did not change when the method changed, and the rankings were also almost the same.

4.3.6 Considerations in scoring the evaluation

The preceding subsections described subjective evaluations. However, when evaluation is difficult because the subjects to be compared are close, a graph as shown in Figure 4.3-1 is useful. The graph can be used to make weighting inclination curves.

4.3.7 Rules for taking a reasonable majority decision on evaluation plans

These rules can be applied to any of the above methods when a majority decision is required. This subsection explains the rules by taking the case of the priority method using a majority decision in Figure 4.3-2.

(1) List the plans to be evaluated, for example, on a blackboard so that (many) voters can see them. Call each plan the 1st, 2nd, 3rd etc,… plan.
(2) The chairman requests the voters to rank all the plans on a piece of paper. The voters must give rankings on this piece of paper instead of presenting their opinions.
(3) After the voters have finished, the chairman records the rankings to the right of each plan as in Fig. 4.3-2. When a majority decision does not produce an almost consistent ranking, the voters who presented far different rankings must explain their reasons so that differing opinions can be considered and adjusted. If necessary, voting is repeated.
(4) After presentation and adjustment by all the voters or additional voting has finished, the score of each plan is totaled, and the resultant ranking of the plans is considered to be the majority decision.
(5) However, when plans with low scores are close in score, a majority decision is taken once again only for them.
(Note) In (3) to (5), when it is difficult to rank the plans, give the plans the same rank. Give the plans every one or two skips, such as 1, 3, and 5 when the difference of the plans needs to be exaggerated.
(Note) When the rules are applied to the DARE Method, simply replace the priority ranking with the ratio values.

4.3.8 Method to immediately combine and select the best structuring plans

This method is efficient when the structured plans to be evaluated can be combined in several ways, and the combination and the selection of the best ones need to be made quickly. That is, this method is efficient

when several structured plans can be made by combining elements, and the combination has a decisive effect on the result. For example, this method is effective when the roles of project members must be decided at the start of a project.

Figure 4.3-3 shows an example of how to decide the roles of project team members by mutual election.

(1) The necessary roles of the team, such as team leader, sub-leader, secretary, and general affairs, are listed so that all the members can see them.

(2) The deciding chairman requests all the members to think of the best combination of the members and roles. The members should first write down their ideas on a piece of paper instead of presenting them orally.

(3) After all the members have finished, each member should present his/her idea, and the chairman records them to the right of the listed roles.

(4) After the presentations, write the total score of each member for each role at the rightmost part of the list. The roles are decided when each role has a member with the highest score for that role.

(5) When there are two candidates with the same score for a particular role, voting is done again for these roles. Then, voting is performed for the remaining roles.

4.3.9 Essentials for evaluation-based decision-making

Although many evaluation techniques have been published, all of them provide only the result of "Difference of Information by Simple Comparison" for decision-making, and forget to emphasize that pieces of "Structured Difference of Information", in which importance is given to the purpose-measure relation (direction of value), should be put together.

A correct decision should be made by the mechanism explained in "Decision-making mechanism based on difference of information," and the following items should be confirmed before discussing evaluation techniques.

(1) Decisions should be made based on the relation between purpose and measures. Persons concerned with decision-making in a complicated evaluation should make a "block diagram of purpose and measures" using the PMD method as needed.

(2) Because decisions are made on the basis of the "difference of information," it is desirable to compare the plans to be evaluated with numerical values.

(3) Because all the ranking and weighting activities for evaluation should be based on the relation between purpose and measures, a "block diagram of purpose and measures" using the PMD method should be referred to.

Because comparison can be made only between 2 subjects, even when comparing more than 3 plans, it is desirable to make the final decision between 2 plans as early as possible. This is because only one piece of "information of difference" is necessary to compare 2 plans, while 3 pieces of "information of difference " are necessary to compare 3 plans. This is confusing for those concerned.

Decisions should be made for future activities. The six conditions in Figure 4.3-4, including the above description, are required.

Making the best use of the evaluation techniques requires collecting and preparing the necessary information in advance.

4.3.10 Discussion

This chapter describes simple, reasonable, and practical methods for pre-evaluation from a rational perspective. Although there are other good methods, such as the Analytical Hierarchy Process Method briefly explained in Section 3.1, they are not discussed in this chapter because they select one plan only after ranking many plans, and are, therefore, not efficient in terms of time and work.

"Considerations in scoring the evaluation" of subsection 4.3.6 and "Rules for taking a reasonable majority decision on evaluation plans" of subsection 4.3.7 come from the author's own thinking and have never been published by anyone else. The author has used the procedures of the two subsections in his practical work. These methods are introduced in this chapter because they assist the DTCN method, and are required in the Design To Cost Method in Chapter 6 and later on. As described in Section 3.1.9f, the above-mentioned evaluation methods are more effective when combined with the PMD Method. The PMD method is effective and reasonable as a way to reach a situation where the above methods can be used properly.

Tabe 4.3-1 Example of priority method

Evaluation element / Plan	Cost Priority	Weight Priority	Reliability Priority	Feasibility Priority	Total Count	Notes	Total priority
Plan A	2	1	1	1	5	Cost difference between plan A and plan B is very small	1
Plan B	1	3	2	3	9		2
Plan C	3	2	3	2	10		3

Table 4.3-2 Priority of evaluated elements to select the engine air inlet port direction for a twin-engine helicopter

Evaluation element (A)		Judgment (B)						Count (C)	(C)+1 (D) Note	Importance (E)
		1	2	3	4	5	6			
1	Aerodynamic resistance	0	0	0				0	1	0.1
2	Maintenance on aircraft	1			1	0		2	3	0.3
3	Installation and removal of engine		1		0		0	1	2	0.2
4	Foreign object defect (FOD)			1		1	1	3	4	0.4
								Total	10	1.0

(Note) Originally Fasal started the priority from zero.
T.Fujita improved the method by adding "1" to the Fasal result in order to avoid dividing zero when getting a weighting coefficient.

Table 4.3-3 Example of no algorithm in "0-1" comparison

Evaluated element	Judgment			Count
	1	2	3	
A	1	0		1
B	0		1	1
C		1	0	1

Table 4.3-4 Comparison result for selecting the air-inlet direction for helicopter engine

Evaluation element		Aerodynamics (Resistence)		Maintenance onboard		Installation maintenance		Foreign object defect		Total score
Weight		0.1		0.3		0.2		0.4		
Plan		Score	Score × weight coeff.	Score	Score × weight coeff.	Score	Score × weight coeff.	Score	Score × weight coeff.	
1	Upper inlet	80	8	20	6	100	20	10	4	38
2	Side inlet	50	5	100	30	100	20	100	40	95

Table 4.3-5 Example of DARE-Method

Column A Column B Column C Column D

Evaluated element	Ratio when compared with "C" column of next low row	Ratio when compared with lowest "C" column row(1.0)	Weight
1. Initial investment	2.0 →	0.66	0.10
2. Salvage value	0.1 →	0.33	0.05
3. Air pollution	2.5 →	3.25	0.50
4. Development period	1.3 →	1.3	0.20
5. Operation cost	——	1.0	0.15
Total		6.54	1.0

Table 4.3-6 The result of compared evaluations when side inlet(plan) is "1.0"

Evaluation element		Aerodynamics (Resistance)		Maintenance onboard		Installation and removal of engine		Foreign object defect		Total Score
Weight		0.1		0.3		0.2		0.4		
Evaluation plan		Ratio score	× weighting coeff.	Ratio score	× weighting coeff.	Ratio score	× weighting coeff.	Ratio score	× weighting coeff.	
1	Upper inlet(plan)	1.5	0.15	0.5	0.15	1	0.2	0.1	0.04	0.54
2	Lower inlet(plan)	1	0.1	1	0.3	1	0.2	1	0.4	1.00

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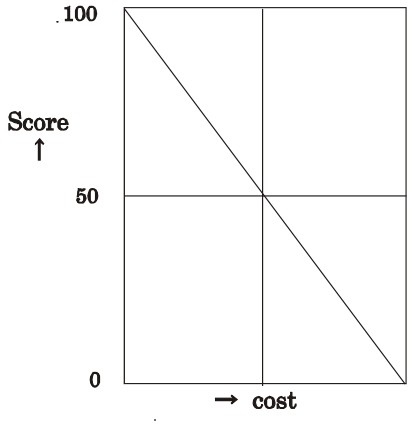
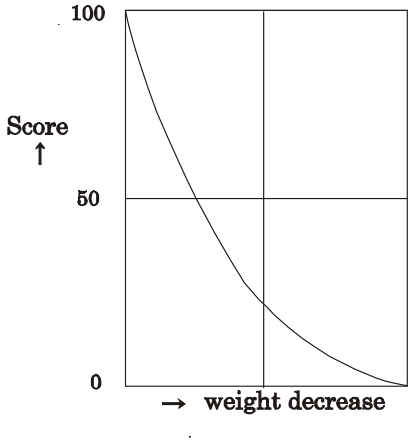
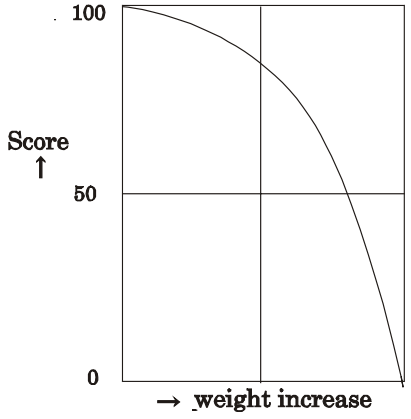
Fig. 4.3-1 Weight inclination curve



(1) Proportional relationship



(2) Exponential relationship



(3) Inverse exponential relationship

Fig. 4.3-2 Rationale rule to decide the evaluated plan by the majority
(In order to keep the importance of majority opinion, because sometimes majority opinion is the more important)

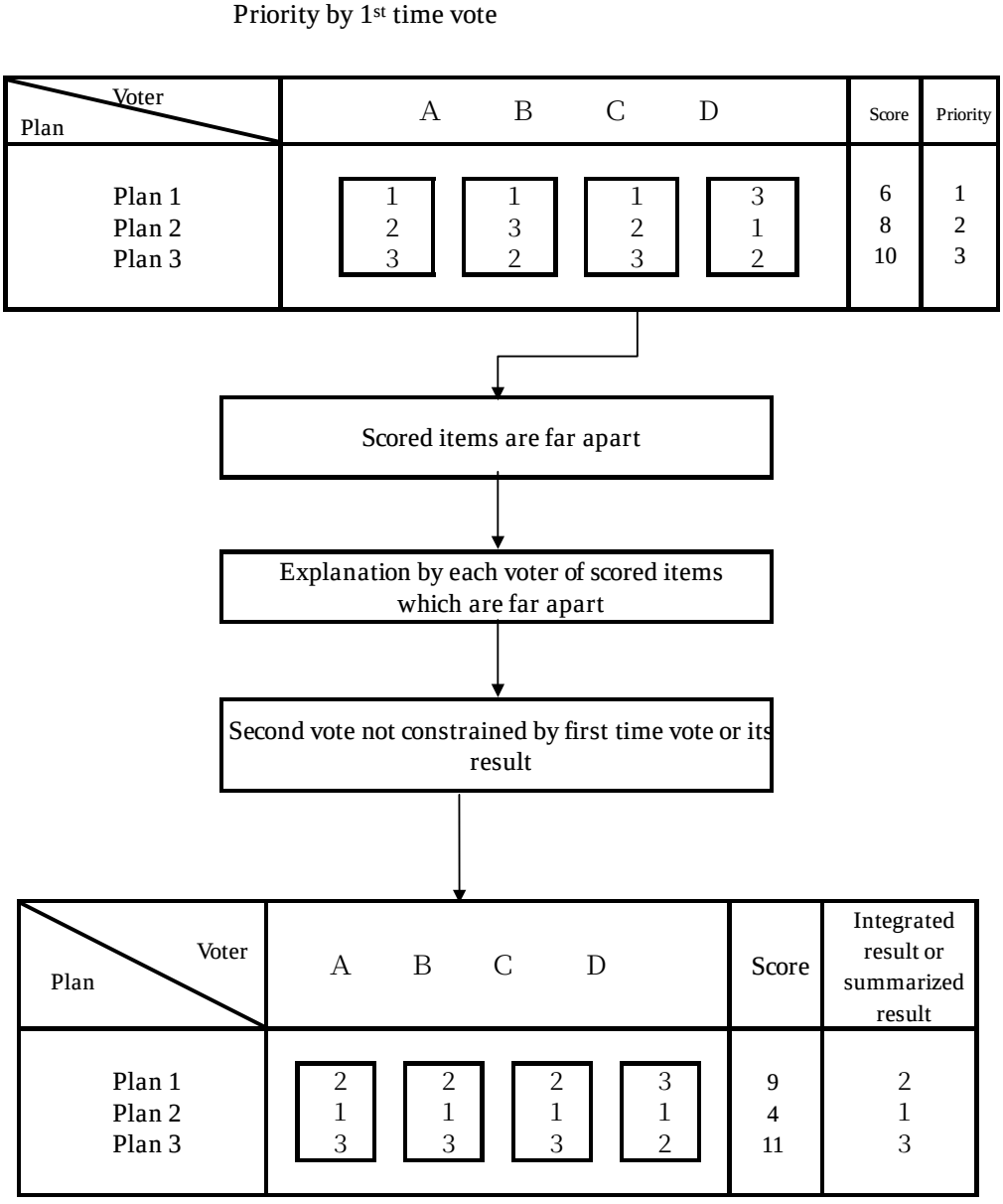
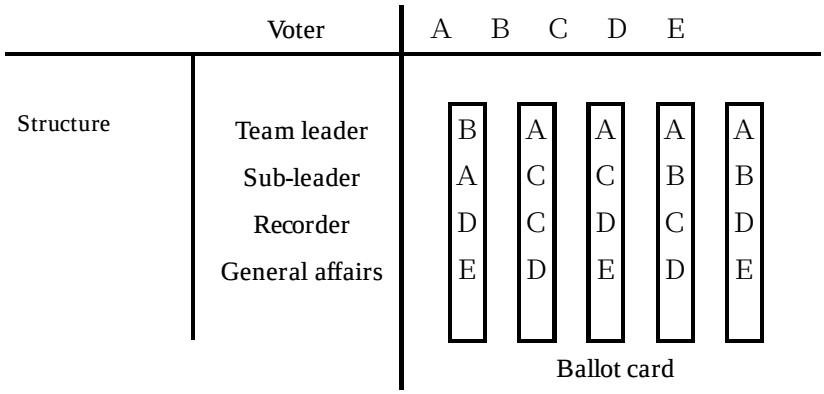


Fig.4.3-3 Method to create the plan of structure and to select it at the same time (by the example of a mutual vote)

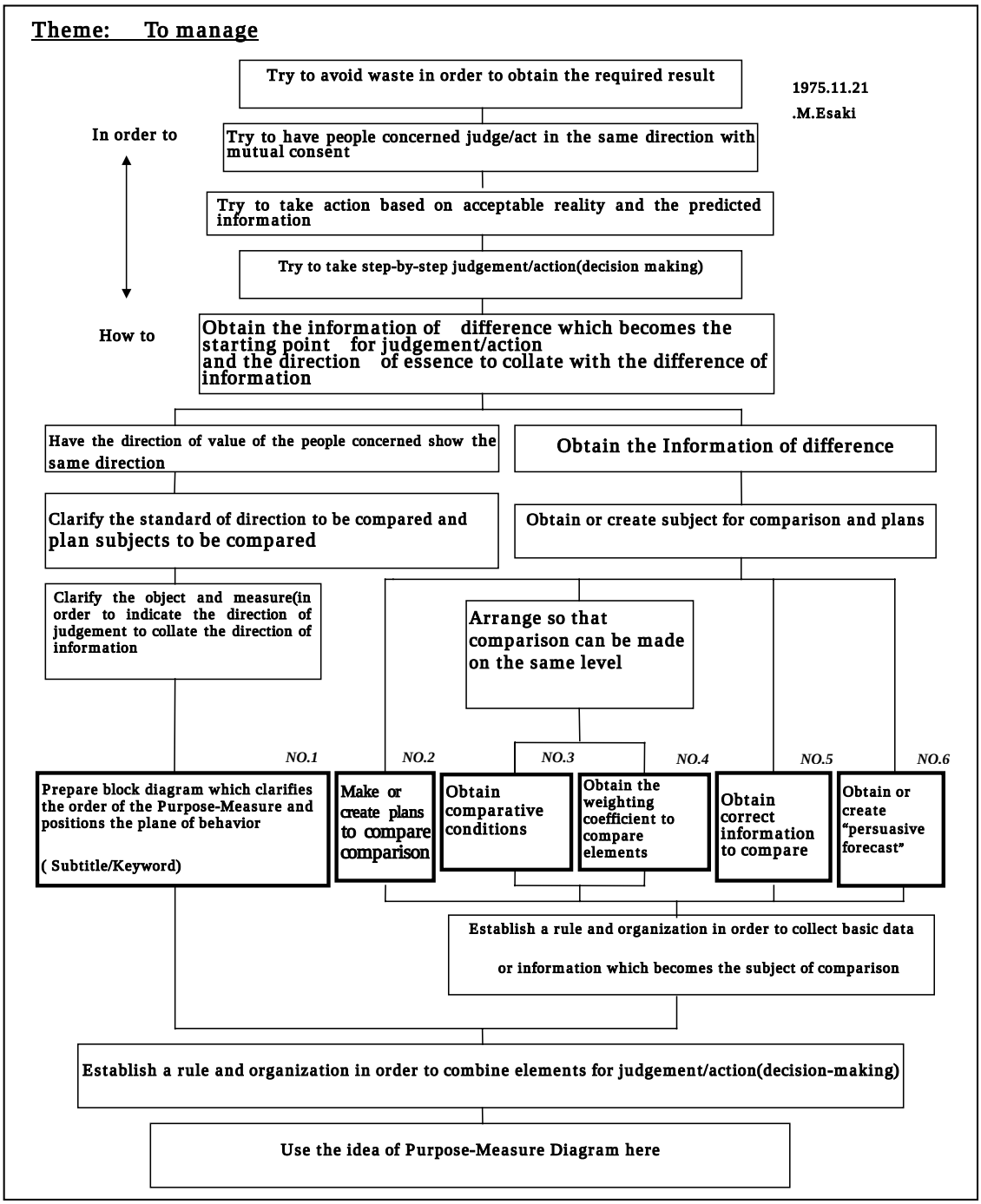


Voting results written on black board

	Role	A B C D E	Summery
First time voter	Team leader Sub-leader Recorder General affairs		"A" decided because of super majority Re-vote assuming "A" is leader
2nd time voter	Sub-leader Recorder General affairs		"B" is decided "C" is decided "D" is decided

Fig.4.3-4 Essential conditions for decision-making in management

Purpose-measure diagram shows six required conditions for decision-making in management



Episode 12 Explanation of ambiguous terms

In Episode 2, it was shown that PMD can be used to study language. In this episode, some ambiguous terms and their uses will be explained for practical work.

(1) What is “to examine”?

The word “examine” is commonly used, but it is not easy to clarify what it means.

To examine is to consider two or more alternatives, and compare them to select the best one among them.

The above “to consider two or more alternatives” includes “to consider to do or not to do.” The terms “verify” and “evaluate” are used for the examination. In the following paragraphs, the contents and purposes of verification and evaluation will be discussed.

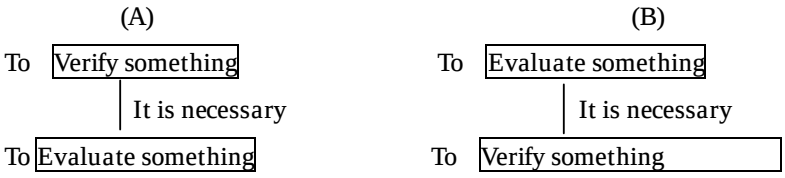
(2) To verify

The word “to verify” is easily used, but its contents are not always clear. This is particularly true when it is necessary to verify a future issue. To solve the problem, it would be better to first clarify whether the word “verify” is used for a future or past issue because the steps for verification are completely different between future and past issues. The meaning of “to verify a past issue” is easily understood. One of the clearest examples is to verify a crime. All you have to do is to prove the facts that only the criminal knows, using evidence, alibis, and witnesses.

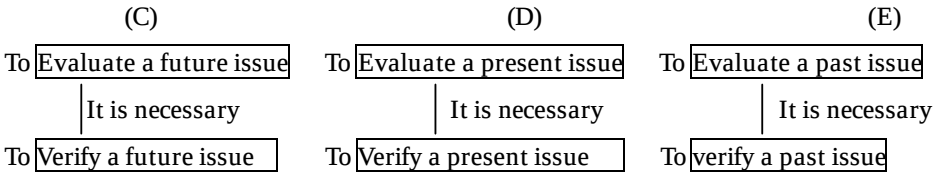
What are the contents of “to verify a future issue”? There is no physical evidence because the issue belongs to the future. Therefore, “to verify a future issue” is to use previous trends, independent ways of thinking, or insert conditions to make people believe that the issue will be solved, that is, to make up a structure that leads people to recognize the steps and procedures to solving the issue. The structure is used to obtain their understanding. This interpretation is the same as the contents of the “Persuasive prediction” in the Chapter “Decision-Making Mechanism by Difference Information.”

(3) Relation between the terms, “verify” and “evaluate”

The relation between the terms “verify” and “evaluate” can be expressed through PMDs as follows:



Which is the more reasonable order? If both seem reasonable, it would be due to the lack of proper use of past and future verification. The following figures show the PMDs for future evaluation and verification, present evaluation and verification, and past evaluation and verification:



The word “to evaluate” includes future, present, and past aspects. Therefore, “to verify” is also used properly for future, present, and past aspects. Future verification is to persuasively explain future possibilities; present verification is to confirm and explain current status; and past verification is to prove a theory with evidence. Both “verify” and “evaluate” have completely different steps for future, present, and past issues.

(4) Let's think about the word “evaluate,” in detail, in terms of future, present, and past aspects. Because it is a known fact that evaluation is done before a decision has been made, “evaluate” is interpreted here as a pre-decision evaluation. Decision-making is done for a future issue. Therefore, to make a decision for a future issue requires evaluating a future issue (future evaluation).

In general, the term, “evaluate,” is used to decide something good or bad, or to make a relative evaluation by weighing and scoring various factors. “Evaluate” is the combination of “E” or “Ex” and “valuate,” and therefore includes the meanings of to “create a value” and “emphasize a value.” Therefore, to make a future evaluation is to create a future value,” and value creation is possible only when there is the relationship between purpose and measures, as described in the section on the decision-making mechanism.

In other words, to make an evaluation (to create a value) is possible only when there is a relationship between purpose and measures (PMD). Therefore, it is meaningless to evaluate something by scoring and decision-making unless discussion is done in advance on the basis of a PMD (purpose-measure diagram).

Conclusion

In conclusion, to make a future evaluation is to prepare a PMD showing the relationship between purpose and measures in the future, and compare and evaluate alternatives at the Key Word level of the PMD.

Episode 13 Contents of the terms, "abduction," "verification," "evaluation," and "decision-making"

Whereas Episode 12 clarifies the terms "verify" and "evaluate" to some degree, in this episode, the way of thinking and actions corresponding to the terms, "abduction" and "decision-making," which should be performed before and after verification and evaluation, will be discussed. As described in Episode 12, both "verify" and "evaluate" are used for future and past aspects. Therefore, 'to abduct' is divided into past and future abductions, and 'decision-making' into past and future decision-making.

With the way of thinking of Design To Customer Needs discussed in this book, it is easy to prepare a PMD of "abduction," "verification," "evaluation," and "decision- making" in the future.

Using the PMDs of "abduction", "verification", "evaluation" and "decision-making" in the future, the models corresponding to those in the past were studied. As a result, the following figure showing the relationship between a steplist and the PMD procedure was obtained:

(1) Future decision-making — Make decision for the future issue
↑ It is necessary
(2) Future evaluation — Evaluate the future issue
↑ It is necessary
(3) Future verification — Verify the future issue
↑ It is necessary
(4) Future Abduction(or hypothesis)-making — Abduct the future issue

According to the PMD and Steplist management form framework,

(1) A decision is made by moving from the secondary information collection stage of the 4th stage of the steplist to the basic items of the 5th stage (change from an inductive to a deductive approach)

(2) The contents verified for the future which are created in idea and breakdown structuring phases are evaluated toward the future in the second information collection phase of the steplist form.

(3) Based on the Abducted expression (key word), Fist information collection, idea creation and structuring- related jobs are done in the steplist form framework so that the realization of the key word (Expression of the future abduction) can be believed to be realized as the future matter.

(4) A PMD is prepared and the expression of abduction for a future issue is made with the key word.

The following is an example to explain the contents:

Because the author now teaches in a university, the process for a student to complete a graduation thesis

is used as an example.

(1) A PMD, as shown in Figure 1, is prepared.

(2) The graduation thesis is completed according to the PMD. Figure 2 is the steplist until the student is satisfied with it (8E in the steplist).

(3) Figure 3 is a list of the example process from the stage of the abduction to the stage of full decision-making before the production of "Desk for easy study".

By comparing Fig. 3 with Fig. 1 and Fig. 2, we can recognize that Fig.1 corresponds to the process of future abduction "as to complete the thesis" and that Fig. 2. corresponds to the procedure contents to materialize the future result abducted expression of "to complete the thesis."

Fig. 3 shows the structure creating contents of future result abduction, verification, evaluation, and decision-making.

There have been only 2 books about abduction in Japan since World War II .

(1) Nakayama, Masakazu, Deduction, induction, and abduction, (Sanno University Press, 1974)

(2) Tobioka, Takeshi, Way of Thinking with Abduction, (Goma Press, 1994)

The thinking of Abduction is referred to by Charles S. Peirec (1839-1914, United States) as the essential scientific way of thinking, together with induction and deduction. However, he did not mention how to make the procedure a abduction (or hypothesis), and only unedited papers remain after his death.

Therefore, there are no papers or books which explain the procedure how to make and properly use past and future abduction-making in a visible form.

In this setting, this episode is useful.

Abduction (or some time hypothesis), verification, evaluation and the approval of decision and for past issues, such as the result of natural mechanisms and crimes, were clearly used because they were based on evidences that already exist.

However, although those for future issues were based on past evidence, the contents for each step for future were not clear because evidence did not exist before a decision was made.

This episode is the first explanation showing that this only works with clear causal relations from the primary information collection for PMD and steplist to the secondary information collection. Subsequent stages have to be carried out to make a future abduction (or hypothesis), verification, evaluation and decisions. This is detailed in Figure 3.

This example is the preparation of a PMD and steplist for the theme “a desk suitable for study,” which leads to the decision that the desk itself is built. That is,

(1) There are large and small meanings of abduction-making, verification, evaluation, and decision-making.

(2) The large meaning of abduction-making, verification, evaluation, and decision-making is the process shown as Line A in Figure 3. The contents are expressed as the work steps of the corresponding PMD and steplist in column of Line B. Space of column C is an image of the work of each steps.

The column A~C and D~E in figure 4 show the contents of the large and small meanings of future abduction, verification, evaluation, and decision- making

Lines D and E explain the contents of the small meanings of abduction (or hypothesis)-making, verification, evaluation, and decision-making.

The evaluation criteria at each step become definite by the value method expressed by the PMD, and by the movement from the output of the causal relation of the steplist showing the procedure in this figure to the next input.

Discussion

This episode explains the relation of future abduction, verification, evaluation, and decision-making that have existed and the issues to clarify their contents.

(1) The use of a PMD and steplist allows for the clarification of the term, “future abduction” and the implementation of what to do for each theme/issue.

(2) At the same time, the use of a PMD and steplist allows for the clarification of how the contents of “evaluation criteria” change step by step, and how they are positioned.

(3) Because a PMD shows the repetitive relationship between purpose and measures and focused or abducted expression, i.e. Main Key word expression, it can clearly show the way of thinking for “The future abduction.”

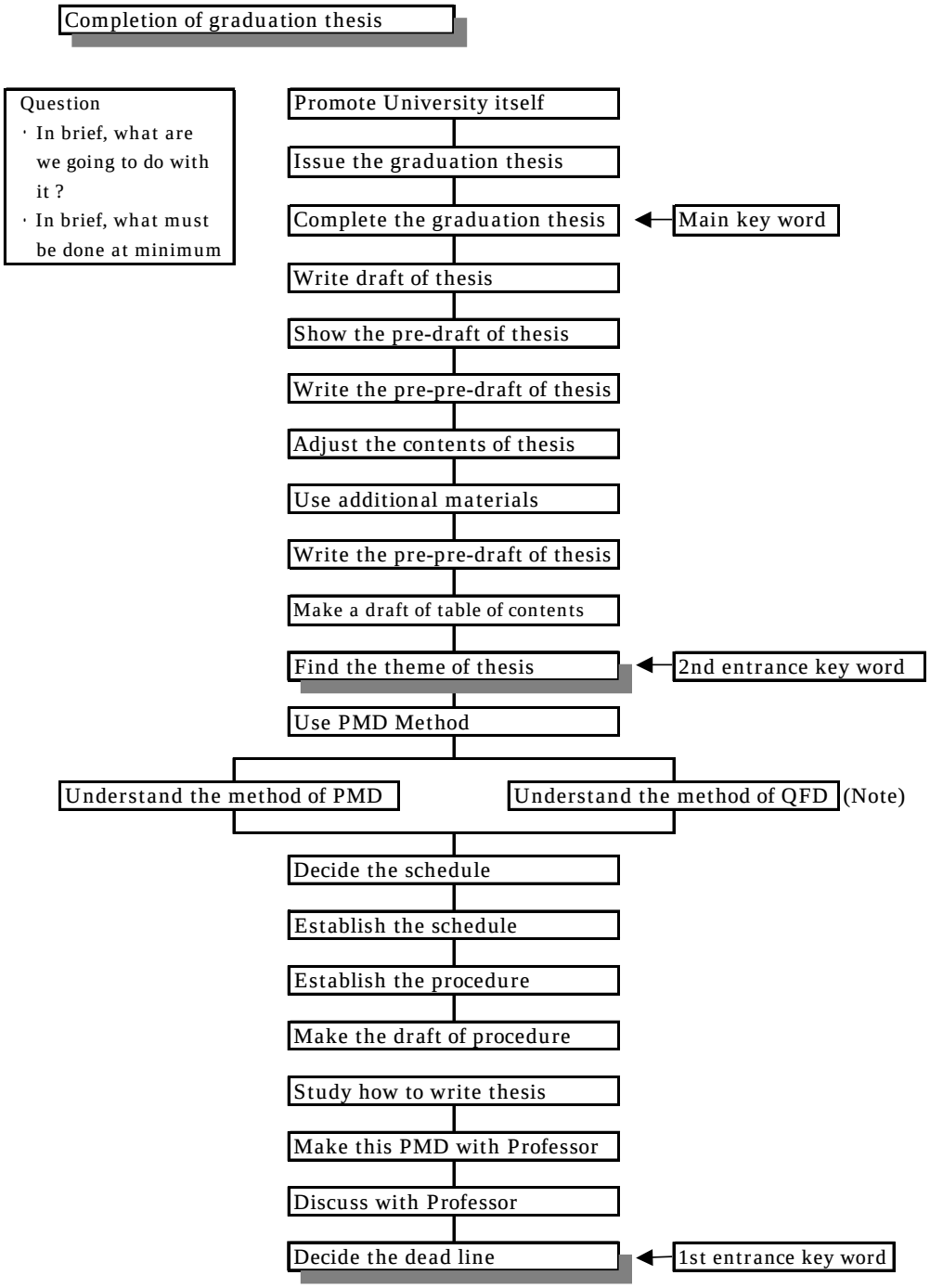
Fig.4 shows the case steps to create the intentional future by the future abduction, verification, evaluation and decision-making for full scale implementatin.

This can be done for existing or past phenomena using the way of thinking shape of Result-Cause Diagram (RCD) which shows the vertical result-and-cause relationship diagram of existing or past phenomena and by the Steplist starting from it for the contents of “The scientific abduction, verification,

evaluation, and affirmation" of past process or phenomena.

Also, this can be done for future natural phenomena using the way of thinking shape of Future-Result-Cause Diagram (FRCD) which shows the vertical future result-and-cause relationship diagram of future natural phenomena and by the Steplist starting from it for the contents of "The future scientific abduction, verification, evaluation and affirmation" of future natural results or phenomena.
Note: The techniques, CRD and FRCD, will be presented in anther paper by author (1998). (See the details in the appendix H of this book)

Episode 13 Fig. 1



(Note) QFD: Quality Function Deployment

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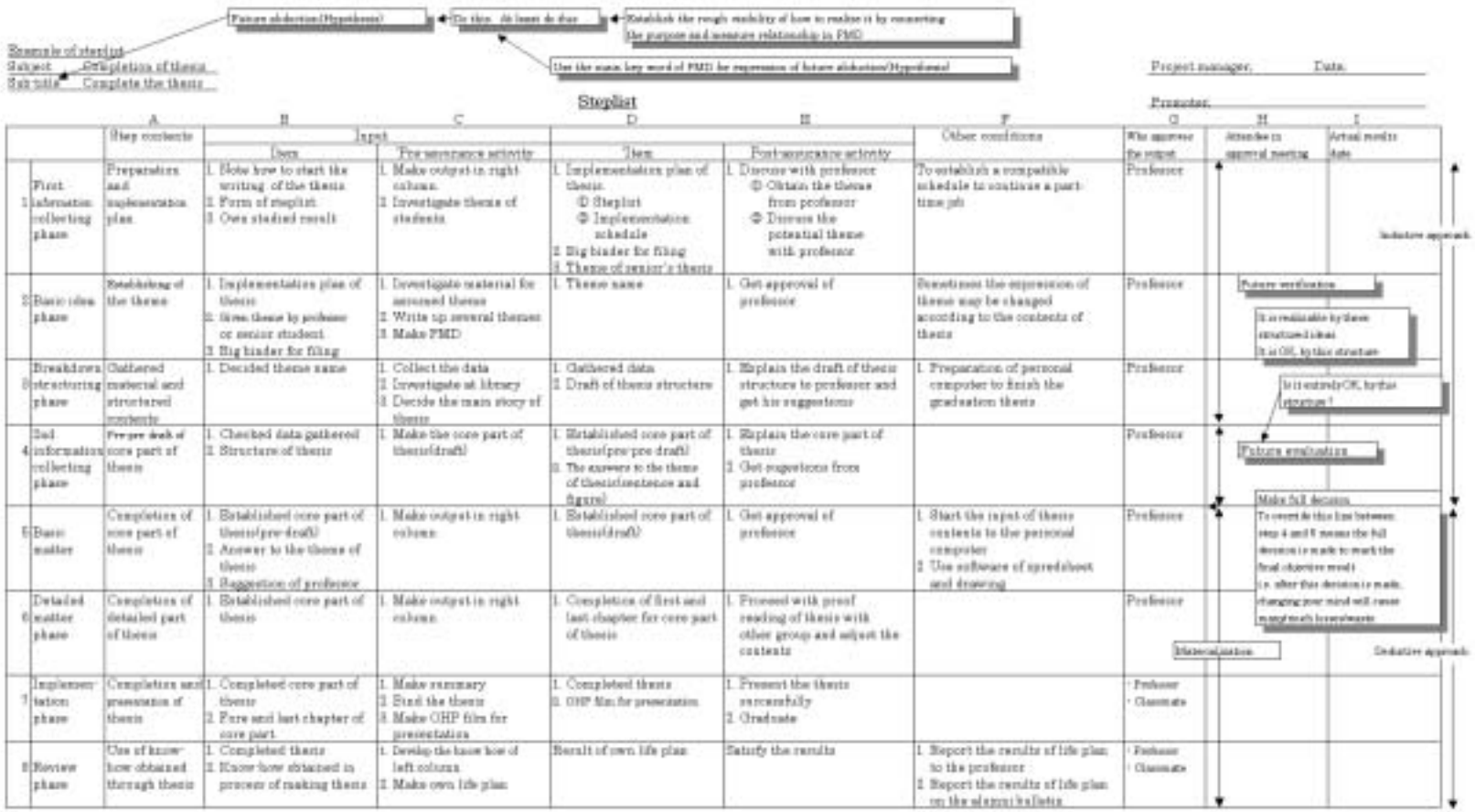
Episode 13 Fig. 2



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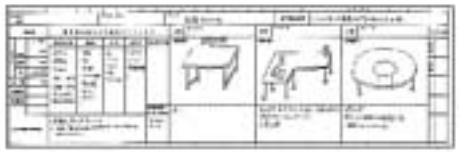
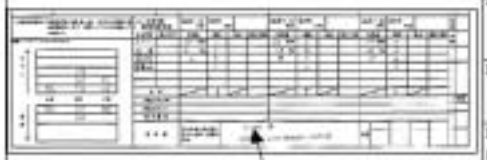
Episode 13 Fig. 3

Example of future abduction, verification, evaluation, full decision-making for "desk for easy study development"

	A	B	C	D	E
	Basic process of abduction verification, evaluation, full decision-making in wide meaning	Corresponding work by PMD and steplist	Example of actual working by PMD and steplist	Narrow meaning of sub-process	Thinking and working contents of abduction, verification, evaluation and decision-making in narrow meaning
Abduction	Abduction	Make PMD	(Theme) 'PMD' 	Abduction	Make PMD
				Verification	Verify whether able to structure a concrete purpose-measure relationship using our knowledge or not by making PMD
				Evaluation	Evaluate PMD, the main key word and entrance key word of PMD from social standpoint
				Decision-making	Decide to move to next step
Inductive approach	Verification	1st information collection	Establish the persuasive, structurized and proofed plan (This means verification)	Abduction	Gather the assumed ideas which can be used to realize the main key word expression
		Basic idea		Verification	Verify whether the ideas are physically feasible or not by drawing the plan drawing from a technical standpoint
				Evaluation	Evaluate the drawn ideas comparison from technical standpoint
		Breakdown structure		Decision-making	Decide to pass the drawn ideas to evaluation meeting
	Evaluation	2nd information collection	Evaluate and compare the structurized plan. 	Abduction	Decide the technically drawn ideas to be the objects to be evaluated in next step.
				Verification	Verify whether the technically drawn ideas have a valuable character for the purpose of PMD or not.
				Evaluation	Create the values by combining each character in drawn ideas from the standpoint of purpose-measure relationship established by PMD
				Decision-making	Judge whether enough evaluation i.e. value creations are made or not before decision is made.
	Full decision-making	Move from 2nd information collection phase to basic matter phase	Decide to proceed the evaluated plan (Issue the order to people)	Abduction	Explain the objective ideas to be selected or decided to concerned people
				Verification	Obtain the opinions before decision is made and adjust the opinions according to PMD
				Evaluation	Evaluate(i.e. create the value of) the objective to be decided from standpoint of social needs and get agreement among the concerned people.
				Decision-making	Decide to proceed the implementation(or making) process of drawn and evaluated ideas.

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Episode 13 Fig. 4

Case to create the intentional future

	Brief expression	Method of how to	Actual example
Random information	_____	Gather information	Recognition of concept of grade of estimate
Preparations for abduction	What are we going to do with it ?	Find the assumed theme expression by using theme PMD method	

Abduction	Grasp the expression of "Do this", "Will do", "OK to do this", "Must to do"	Establishment of main key word by purpose-measure diagram	In brief, just complete the graduation thesis
Verification	Plan and establish the concrete and structured input and output sequence, and parent and children structure to realize the objective result	Proceed the step working contents of information phase, idea phase, break down structured phase	Structure core of thesis,i.e. the main contents and its algorithm of thesis according assumed theme. (If it is necessary, adjust the expression of theme)
Evaluation	Understand the planned structure of objective and evaluate(I.e. Create the value) the planned structure from standpoint of purpose-measure relationship	Implement the work content which is defined as the work contents for 2nd information phase of steplist management before full decision is made	Evaluate(or create the value the core of theme) of thesis as the valuable graduate thesis
Decision of full scale implementation	Decide whether to proceed to process to materialize the plan and evaluate structure or not	Move from the 2nd information phase to basic matter phase of steplist management phase	Decide to get into process to write the detailed and associated part of graduate thesis
GO-A-HEAD	Implement to materialize the planned structure	Implement the work contents for basic matter, detailed matter and completion phase of step-list management form	Complete the graduate thesis and graduate university
After evaluation	Use the implemented result to be useful for society	Review and proceed corrective action as the review phase work of steplist management frame work	· Use and develop the experience and process of the graduate thesis completion (Repeat the value creation) · Think it was the good experience and process of completion of the graduate thesis