A Proposal of Risk Identification Based on the Improved Kepner-Tregoe Program and its Evaluation

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***Abstract*—**Recently project risk management attracts all the attention in order to raise success probability of a project. It is widely known that implementation process of risk management consists of "Risk Management Planning", "Risk Identification", "Qualitative Risk Analysis", "Quantitative Risk Analysis", "Risk Response Planning", and "Risk Monitoring and Control". However there are few bibliographies about any concrete implementation methods of risk management in detail. The authors take up the risk management of a project and above all risk identification, and show a concrete implementation method based on the improved Kepner-Tregoe Program. In this paper, they propose a concrete implementation method of risk identification based on the improved Kepner-Tregoe Program, and show that the method is effective. They perform laboratory experiments on risk identification using the proposed method. Moreover, they compare the proposed method with the widely known methods based on the brainstorming and the original Kepner-Tregoe Program. As a result, they confirm that the method based on the improved Kepner-Tregoe Program is more effective than the method based on brainstorming and the original Kepner-Tregoe Program in terms of generality and efficiency.

***Keywords*—**Risk Management, Risk Identification, Project, Kepner-Tregoe Program.

I. Introduction

RECENTLY, project risk management attracts all the attention in order to raise success probability of a project. In PMBOK Guide [1], the enforcement process of risk management consists of "Risk Management Planning," "Risk Identification," "Qualitative Risk Analysis," "Quantitative Risk Analysis," "Risk Response Planning," and "Risk Monitoring and Control" is defined as consisting of six processes. And the concept is known widely. However, there are few documents, which describe about a concrete enforcement method in detail of these processes, and it is not rare for a method to be different by a person carrying it out. Therefore, in the case carrying out risk management mostly, the precision of the management depends on capability / technology / experience of the members participating in a project, and it is a problem. Especially risk identification is a posteriori process. It is easy to produce unevenness with members in precision of the risk identification than the other work processes when carrying out risk identification without introducing an objective index. Furthermore, it will overlook the risks that are a potential problem if there is deficiency in risk identification. If the examination of this part is light, even if analysis no matter how precisely is done, afterwards, the result of the risk management harms reliability remarkably. The risk identification can be said to be a very important process in risk management from the above-mentioned things. Furthermore, depending on a project, there are times when you must carry out risk management extremely in a short time because of emergency. For example, in the software development projects, the resources for work are cut to satisfy customer requirement conditions, and there is not enough time to carry out risk management. In addition, in the obstacle project to recover the obstacles in a limited time by the counter measures all the resources of the project are taken, and there are cases when the risk management of the recovery work itself becomes insufficient. The problem of not securing enough enforcement time for risk management is not a problem which occurs only in the specialty domains that were extremely limited such as anti-software development project and obstacle measure projects, but the problems occurs in various projects. From the above-mentioned, the project distinguishes risks precisely effectively in limited time, and it is important to grasp them, and to take measures.

So, in this research the risk management in a project is taken up. In the Kepner-Tregoe Program [2], we selected only the potential problem analysis (potential problem analysis is hereafter called KT-PPA) and by using it strictly improved the solution of the problem in risk identification. While proposing the concrete methods of operation of risk identification based on improved KT-PPA in this paper, the validity is also shown. The composition of this paper is shown below. In Section 2,

Manuscript received December 29, 2008: Revised version received February 15, 2009.

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while describing the status quo of the related research on the concrete methods of operation of risk identification, the problems are clarified. And the purpose of this paper is mentioned after an appropriate time. In Section 3, concrete enforcement methods are taken and explain KT-PPA. The section 4, proposes concrete methods of operation. About risk identification, improved KT-PPA is shown and its usage is suggested. Based on these, shown are concrete methods to solve the problems that were shown in Section 2 after appropriate time. In Section 5 the experiments are done and their results are shown. In Section 6, are shown the effectiveness of the enforcement methods of the risk identification that were mentioned in Section 4 by evaluating the experiment result and possibility of the realization. Basically, by comparison of 3 things, widely used brain storming [1] [3] in risk identification, original KT-PPA and improved KT-PPA, shows that improved KT-PPA is the best. In the end, the conclusions of this paper and remaining problem points are described in Section 7.

II. Risk identification related research, and the purpose of this paper

A. Risk identification related research

In PMBOK Guide [1], it is defined [Risk Identification determines which risks might affect the project and documents their characteristics.]. Milosevic [4] says, [The purpose is to find all the risks of having serious influence for the success of a project], then especially henceforth, it discusses by investigating the work of a risk in the process of risk identification.

About the investigation of the risks, some concrete enforcement methods are already suggested although not many. Kino [5] nominates [check list, interview of the intelligent people, brainstorming] as general method used presently for investigation of the risks. And give below the explanation about each method, and the problems when applying to the project are described.

Checklist is a risk table, and continues being advantageous in grasping risks at a glance, but there are problems, which cannot be dealt because of the risk leakage from the checklist. It cannot support in particular the special situation of the individual project.

The interview of intelligent persons is a technique to investigate risks by interviewing the person who experienced similar projects in the past or staff who have good knowledge in the field. It takes time and cost for interview to be efficient to make use of knowledge and the experience of other persons, and there are problems that it is difficult to hear the effective opinions about the novelty of the project

Judging from the viewpoint to investigate risks, the brainstorming can become the most useful tool. However, like the interview of intelligent people, there is the danger that the leakage of risk investigations occurs because it is the method that depends on personal experience and knowledge. In addition, because the brainstorming is performed by protecting 4 rules, ("no criticism at all", "freedom", "demand quantity ", "combination /improvements) [3], in the investigated results there are chances of information unrelated to risks being included.

- The brainstorming is easy to depend on capability, technology, and experience of the members who take part in the project.
- Information unrelated to risks is easy to be included in the investigated product.

Fig. 1 The demerits of brainstorming.

Now, these concrete methods of operation can be classified into the three following types.

(1) Method which depends on the technical field is limited extremely like the software development project, McManus [6] CMU [7], Boehm [8], Kado [9], LEOPOULOS et al.[10], ARSHAD et al.[11], ARSHAD et al.[12], SPREMIC et al.[13]

(2) Method which depends on the limited technical field like the project: PMBOK Guide [1], Royer [14], Smith et al. [15], and Tajima [16] and Kino [17]

(3) General-purpose method which is not limited to a project and can be used in all fields: Kepner et al. [2] and Hoshino [3]

Checklist or interview of intelligent people can be classified into (1) and (2), and brainstorming and KT-PPA can be classified into (3).

B. Purpose of this Paper

Since there are strong and weak points in each of the methods taken up in 2.1, it is better to use two or more methods together to reduce the leakage of risks identification.

For example, in a software development project, not only software, but also the apparatus, which runs the software and people who do work, need to be considered as the object of risk management, many things need to be handled. If risk information is collected based on the method depending on a technical field after collecting risk information based on general-purpose method, it is more extensive and it is considered with less leakage for risk information.

However, since a project is unsteady work, it can be said that the risk identification method dependent on the technical field cannot be used always. Therefore an opportunity to collect risk information only by a general-purpose method in a project increases.

However, since a problem (Fig. 1), which was described in 2.1 is among the brainstorming generally used as a general-purpose method, when using in a project, risks may not be extracted effectively.

That is, if defects are found in the inquiry of risks based on the brainstorming, which is a general-purpose method, potential problems of risks will be overlooked, and if examination of this portion is not deep, even if further analysis

is precise, the results of risk management will spoil reliability remarkably.

Therefore, extract arguments only to the phase, which applies the general-purpose method for risk identification in this paper, and as a general purpose method for risk identification widely used as concrete methods of operation for solving the problems which the brainstorming has, it proposes using the method which improved the rational thinking method for the management called the Kepner-Tregoe Program (only for "potential problem analysis"), and that validity is verified.

III. Kepner-Tregoe Program

The Kepner-Tregoe Program is the "Kepner-Tregoe rational process." Both the psychologist Charles H. Kepner and sociologist Benjamin B. Tregoe discovered that "the prominent decision-making, have the common element of information collection, analysis and judgment process" and systematized this way. The Kepner-Tregoe Program is the rational thinking method (thinking procedure) to use for the scene of management. This Kepner-Tregoe Program intends for making conclusion in everyday business by considering all the thinking domains for the kind of the problems that should be settled by using 4 analysis, problem analysis, decision analysis, potential problem analysis, and situation analysis. The role of each analysis method is as follows.

(1) Problem analysis (PA): The problems that stopped succeeding suddenly from a certain point in time, the cause are studied.

(2) Decision analysis (DA): For the objective achievement, the optimum one is selected from two or more choices.

(3) Potential problem analysis (PPA): While analyzing future risks from known information at present, the policy for avoiding or reducing risks in advance is drawn.

(4) Situation analysis (SA): For each of the partial problems analyzed by given problems, which analysis method from (1) - (3) to be applied is clarified, and in what order they should be applied is drawn.

The Kepner-Tregoe Program is constituted as mentioned above from four analysis methods. However, each of them differs in objectives and also in application procedure respectively. For this reason it is not appropriate to treat them same in confusion under the name of Kepner-Tregoe Program

Therefore, in this research, we only selected a potential problem analysis of the technique for risk management in the Kepner-Tregoe Programs, and discussed. About the KT-PPA, although there is advanced research by Takata [18], Altier [19] [20], Sawai [21], Komiya et al. [22], there is still no report taken up about improvement of KT-PPA this time.

By the way, the risk identification of KT-PPA is a kind of checklist method [3]. In KT-PPA "the dangerous place" that seems to bring bad influence for the achievement of the enforcement plan is called vulnerable areas. The high part of the probability that the problem, which is likely to be brought up will occur is defined as a vulnerable areas, and the following [R1] - [R6] are mentioned as vulnerable areas in KT-PPA. And if a risk is probed centering on these areas based on the fact that such areas exist in a project, it is supposed that risks can be probed effectively.

[R1]: The point that is filled with inexperienced elements.
[R2]: The point where resources required for work are restricted
[R3]: The point where time restrictions are especially severe
[R4]: The point, which is easy to receive environmental change
[R5]: The point where two or more sections are involved.
[R6]: The point where that is responsible is not clear.

It is thought that these are effective in narrowing the search space of the risks.

IV. About the Methods of Operation of Risk Identification

In order to solve the problems mentioned in Section 2 in this paper, we propose the method of risk identification with improved KT-PPA. In order to explain this method, the concrete example of project (Fig. 2) [2] and workflow (Fig. 3) show the procedure of risk identification. The workflow (Fig. 3) is the improved form of original workflow of KT-PPA.

The inauguration of the research institute of a government organization was cut down several weeks afterward, and the bureaucrat who ordered management probed the risk.

Fig. 2 An example case of a project for risk identification.

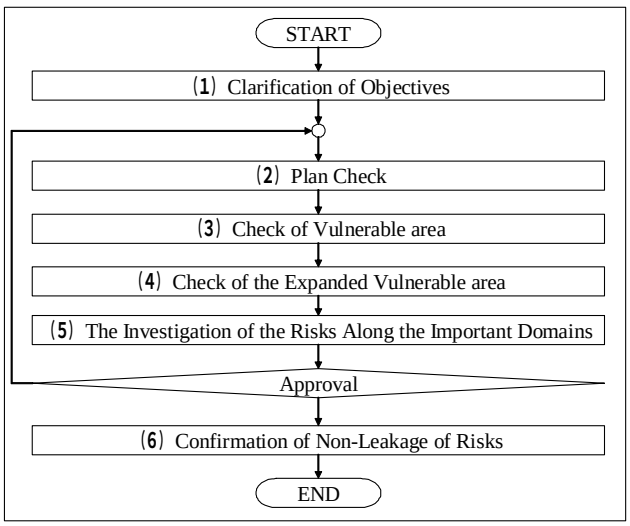

Fig. 3 A workflow of the risk identification.

(1) Clarification of Objectives

Risk management objectives are clarified. . "What will be performed, how much and when?" is clarified.

Multiple government offices and high official of several

countries are going to attend, without any revision. The bureaucrat in charge of completion ceremony administration had an aim to "let a completion ceremony succeed".

(2) Plan Check

In order to assume future risks, the contents of a plan of a project are checked.

The bureaucrat acquired the fundamental information about an inauguration.

• Many high officials are going to be present as guests on the day.

• The building of the research institute was not built to accommodate many people.

• Since this organization was taking charge of the high scientific inquiry of concern, surrounding expectation also seemed to be great and the visitor were likely to be many.

• Kramer senator is to make a primary policy speech.

• Since millions dollars of fund is already injected so failure is not allowed in the inauguration event.

Moreover, when the day schedule was checked, it was found that an inauguration consisted of the "opening ceremony", "speech", "lunch", "inspection of institutions", and "unveiling ceremony" as in (Fig. 4).

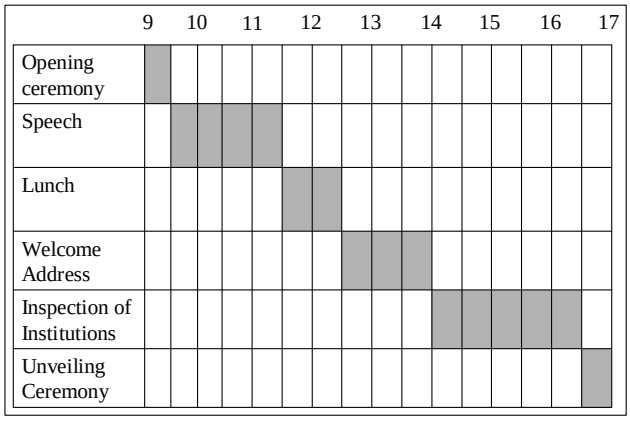

Fig. 4 Schedule of the day of inauguration ceremony

(3) Check of vulnerable areas

In order to probe a risk, the vulnerable areas of a project are checked.

The bureaucrat checked the vulnerable areas of the project along the vulnerable areas of KT-PPA as follows.

[R1]: Correspondence of confusion

[R2]: The size of institutions

[R3]: Time distribution of a program

[R4]: Correspondence of the weather

[R5]: Correspondence of institution inspection

[R6]: Correspondence of lunch

In addition, about each of the vulnerable areas mentioned in Section 3 above, how they will be interpreted in this applicable area and corresponding area for each is raised. However, depending on an application area, about the vulnerable areas mentioned in Section 3, it is possible that there is no applicable area or there are many.

(4) Check of the extended vulnerable areas.

The vulnerable areas of original KT-PPA shows the investigating index of the risk around the point where the probability that a problem occurs is high. However, as by the probability and impact matrix [1] or as in the proposal of Smith et al [15], the general risks are evaluated by occurrence probability and the size of damage when it is obvious to happen. This shows that not only with high probability of occurrence, but with the degree of damage of occurrence can be dangerous risk. In other words there are dangerous risks for the risks that occur with big damages even for things with low outbreak probability. However, in the instructions of original KT-PPA, even for risks which may become big with the damage of occurrence, there is no mentioning of investigating the things with low occurrence probability, so such risks are not investigated and the damage may be big. From such thinking, the new index that we show in figure 5 in the vulnerable areas of original KT-PPA, we propose to add the index [R7], with more detailed indices [R7-1], [R7-2], and [R7-3]. Because from the viewpoint of the project, giving minus that affects to the objectives of the project are giving "low quality", "high cost", and "late delivery". Regarding this we improved the original KT-PPA.

[R7] The point where the possibility to occur is low, but a serious loss occurs when it happens.
[R7-1]: The point where a serious quality fall occurs.
[R7-2]: The point where serious excess cost occurs.
[R7-3]: The point where a serious appointed date of delivery gets delayed.

Fig. 5 An area to add newly to vulnerable area.

The bureaucrat checked the vulnerable areas of the project along the extended vulnerable areas.

[R7]: Progress and the expense of the completion ceremony.

(5) The investigation of the risks along the vulnerable areas.

Along vulnerable areas, risks are investigated. About the investigation work, without being particular about quality of the information such as description methods, collect as many risks as possible

The bureaucrat applied above-mentioned [R1] - [R7], and probed the risks of eight affairs shown below.

1) Was in confusion so applied ([R1]) for where should the people go, and what is good to do.

2) Applied ([R2], which is for unsuitable establishment to treat a lot of attendants.

3) Applied ([R3] for member of the diet and VIP who may not attend as per program.

4) Applied [R4] for hindrance of rain or a strong wind for progress.

5) Applied [R5], in the institution for announcement of research results, where there was a scramble to get the place.

6) Applied ([R6] for eating the lunch menu within unsuitable limited time.

7) Applied ([R7] for person in charge who didn't grasp detailed progress.

8) Applied ([R7], which exceeds the budget that planned at first by doing gorgeous direction.

(6) Confirmation of non- leakage of risks.

By reviewing the investigation of risks, confirm that there are no omissions of investigations. The bureaucrat did the investigation of the risks along vulnerable areas and planned a review.

By above-mentioned procedures, it was possible to investigate the risks of the project to hold a completion ceremony. This way by using the improved procedures of KT-PPA, it was possible to investigate the risks within limited time, and manage them effectively.

V. Check of an Application Experiment and its Validity by It

When the 3 methods, brainstorming method (Strictly it is card BS Law. Card BS Law is hereafter called brainstorming. Card BS Law method is known as individually available brainstorming method.), the original KT-PPA, improved KT-PPA are compared, and the improved KT-PPA method proves to be more effective. In addition, the writer learned a law by experience that "the risk identification capability improved more with increased work experience". On this account, on the occasion of an experiment, by testing this law learned by experience was formed.

A. The method of an experiment

[Environment of the experiment]

Because it was not rare to perform the risks identification of the project alone, one person did a comparison test for risks investigation. When risks investigation was done, then opinions were not exchanged with other subjects.

[The subjects used for the experiment]

Three problems were selected to study the risks identification on testing. The summary of the problems is shown in Figure 6, Figure 7, and Figure 8 each. These problems intend that there is a possibility that members will face high level of work items when a project is pushed forward. In addition, we took up the work item (Figure 6) by the software development project and the work item (Figure 7, Figure 8) by the anti-obstacle measure project to show that we could apply the improved KT-PPA method universally. In addition, we decided to take up two high obstacle measures projects of the emergency because there was not enough time to carry out risk identification by the real risk management. By the way, these problems are based on daily work experience, so that it is easy for subjects to remember.

On the Web server of the research room, the applications are being developed. In order to judge the normal operation of the applications, the developer requested another worker to check that there were no grammatical errors. The developer gave the source codes of the applications to a worker in writing. The worker will perform the visual confirmation of the source codes from now.

Fig. 6 A work item of a software development project (Problem 1)

When the file server of the research room was checked, it was confirmed that the Access Privileges of the server were not appropriate. It was found that the software under development in the research room sets the Access Privileges. Investigation results proved that there were problems for setting. The settings were changed urgently.

Fig. 7 A work item of a trouble-shooting project 1 (Problem 2)

When the file server of the research room was checked, it was confirmed that the Access Privileges of the server were not appropriate. It was found that the software under development in the research room sets the Access Privileges. Investigation results proved that there were no problems for setting. Reboot of the software or the reboot of the server is necessary to correct them, so repair work need to be done urgently.

Fig. 8 A work item of a trouble-shooting project 2 (Problem 3)

[The allotment method of the subjects and the work contents of each group]

Total of 25 persons were allotted as subjects in 5 groups, each with 5 persons. Three groups, Group α, β, δ were divided so that the ability of the subjects between them was uniform. In addition, two groups of group γ and ε were grouped so that the ability of the subjects between these became uniform.

The contents of work of each group and the subjects of each group are as follows. In addition, in the experiment, with the experience of risk management less than a year, were defined Beginner Class, from 1-5 years were defined as Middle Class, and more than 5 years were defined as Upper Class.

Group α:

Five beginners' class persons who have been engaged in the same project for more than 1 year were made into the subjects to investigate the risks with improved KT-PPA.

Group β:

Five beginners' class persons who have been engaged in the same project for more than 1 year were made into the subjects to investigate the risks with original KT-PPA.

Group γ:

Five middle-class persons who have been engaged in the same project as for more than 1 year were made into the subjects for investigating the risks with original KT-PPA.

Group δ:

Five beginners' class persons who have been engaged in the same project for more than 1 year were made into the subjects to investigate the risks with brainstorming.

Group ε:

Five middle-class persons who have been engaged in the same project for more than 1 year were made into the subjects to investigate the risks with brainstorming.

[The enforcement procedures of the experiment]

The experiment measured the results of the effects of each of the 5 groups and compared them. The enforcement procedures of the experiments are as follows.

STEP1:

The subjects are assembled, and the method of investigating the risks is defined. Explanations are made until all the participants understand how to probe risks.

STEP2:

The subjects are assembled and the outlines of the project taken up for the experiment are explained.

STEP3:

The subjects perform risks investigations. The subjects probe the risks as per specified method and list up the risks. The subjects record the risks on the cards. And this time they record 1 risk on 1 card. The work on Problem 1 and Problem 2 are finished each in 15 minutes, and the Problem 3 is finished in 30 minutes. The time difference of Problem 2 and Problem 3 was made to check that whether the time required for investigating varies or not for 3 methods of brainstorming, original KT-PPA, and improved KT-PPA.

STEP4:

The upper persons of risk management check the contents of the experiments. Fundamentally by dividing the investigated data in [risks], [risks irrelevant information] the correct data and wrong data are classified.

In the experiment, the information set up by operative measurement is acquired as experimental data.

B. Experimental results

[Example of correct and wrong data obtained in the experiment]

In the data obtained in the experiment, the chances are that besides correct risk data [correct data], there will be risk irrelevant data [wrong data] by selection mistakes. It is important to identify both the data, when summarizing the experimental data. In the experiment the examples of risks classified as correct data are shown in Figure 9. In the experiment the examples of risks classified as wrong data are shown in Figure 10.

- Since codes are checked visually a clerical error may be overlooked.
- During the reboot of a server, hardware failure may occur and the server may be unable to be started.
- Although the access rights problems were solved, other problems may occur and use of a file server may become impossible.

Fig. 9 Examples of identified risks.

- How much will be the quantity of the source code to check?
- It was confirmed that the Access Privileges of the server were not appropriate.
- Investigation results proved that there were no problems for setting.

Fig. 10 Examples of the irrelevant information for risks.

[About summarizing the data obtained in the experiment]

Risk identification is cognitive and a posteriori (a posteriori) process. When testing, enough consideration is necessary for selection of the subjects and the grouping of the subjects. When testing, select subjects after having examined their ability, technology and experience. And it is necessary to make grouping based on these levels. Reliability of the experiment may be lost unless the data is collected by gathering lot of uniform talented people with ability, technology, and experience. However, it is almost impossible to gather a lot of such talented people in the real problems. On this account it is difficult to rely on numbers statistically, and to prove it. Therefore, cannot help but adopt another method. On this account use conformity rate [24] and reproduction rate [24].

Thinking about the situations as in Figure 11. In this case, the set ***A*** of the risk that should be identified [correct data], the set ***B*** of the data generated by method ***X***, and the set ***C*** of the selected correct data by method ***X***, and ***P***(precision ratio), ***R***(recall ratio) and ***F*** values for each are shown in the following formula, respectively.

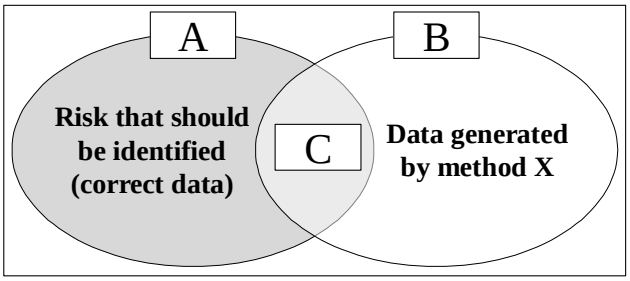

Fig.11 - A Venn diagram for explaining the difference between precision ratio and recall ratio.

$$R = \frac{C}{A} \qquad (1)$$

$$P = \frac{C}{B} \qquad (2)$$

$$F = \frac{2 \times P \times R}{P + R} \qquad (3)$$

Now, in extraction work of risks, the data extracted by groups α, β, γ, δ, ε including the wrong data collected as α, β, γ, δ, ε respectively. If all the data selected by mistake [irrelevant risk data] are summarized as ***E***, the corrected risk data selected by each group can be shown as below.

Group α : $\boldsymbol{\alpha} - E = \boldsymbol{\alpha} \bigcap E^{C}$

Group β : $\boldsymbol{\beta} - E = \boldsymbol{\beta} \bigcap E^{C}$

Group γ : $\boldsymbol{\gamma} - E = \boldsymbol{\gamma} \bigcap E^{C}$

Group δ : $\delta - E = \delta \bigcap E^{C}$

Group ε : $\varepsilon - E = \varepsilon \bigcap E^{C}$

- Precision Ratio:

Because it is only group α that worked on risk extraction with improved KT-PPA, the precision ratio of the risk extraction work by improved KT-PPA can be expressed by the next formula.

$$\frac{\boldsymbol{\alpha} - E}{\boldsymbol{\alpha}}$$

Because it is only group β and γ that worked on risk extraction with original KT-PPA, the precision ratio of the risk extraction work by original KT-PPA can be expressed by the next formula.

$$\frac{(\boldsymbol{\beta} \cup \boldsymbol{\gamma}) - E}{\boldsymbol{\beta} \cup \boldsymbol{\gamma}}$$

Because it is only group δ and ε that worked on risk extraction with brainstorming, the precision ratio of the risk extraction work by brainstorming can be expressed by the next formula.

$$\frac{(\delta \cup \varepsilon) - E}{\delta \cup \varepsilon}$$

- Recall Ratio

Because the denominator of the calculating formula of the recall rate is the whole of the correct risk data, which should be extract by general-purpose technique, it can be expressed as in the next formula.

$$\boldsymbol{\alpha} \cup \boldsymbol{\beta} \cup \boldsymbol{\gamma} \cup \delta \cup \varepsilon - E$$

Because it is only group α that worked on risk extraction with improved KT-PPA, the recall ratio of the risk extraction work by improved KT-PPA can be expressed by the next formula.

$$\frac{\boldsymbol{\alpha} - E}{\boldsymbol{\alpha} \cup \boldsymbol{\beta} \cup \boldsymbol{\gamma} \cup \delta \cup \varepsilon - E}$$

Because it is only group β and γ that worked on risk extraction with original KT-PPA, the recall ratio of the risk extraction work by original KT-PPA can be expressed by the next formula.

$$\frac{(\beta \cup \boldsymbol{\gamma}) - E}{\boldsymbol{\alpha} \cup \boldsymbol{\beta} \cup \boldsymbol{\gamma} \cup \delta \cup \varepsilon - E}$$

Because it is only group δ and ε that worked on risk extraction with brainstorming, the recall ratio of the risk extraction work by brainstorming can be expressed by the next formula.

$$\frac{(\delta \cup \varepsilon) - E}{\boldsymbol{\alpha} \cup \boldsymbol{\beta} \cup \boldsymbol{\gamma} \cup \delta \cup \varepsilon - E}$$

For experiments 1, 2 and 3, the results of the application of above expression are shown in Table 1, Table 2, and Table 3 each.

Table 1 Result of Experiment 1

	Group α		Group β		Group γ		Group δ		Group ε	
Method	Improved KT-PPA		Original KT-PPA				Brainstorming			
Experience	Beginners		Beginners		Middle Class		Beginners		Middle Class	
Total number of subjects	5		5		5		5		5	
	5		10				10			
Select data (Included errors)	$\boldsymbol{\alpha}$	71	$\boldsymbol{\beta}$	64	$\boldsymbol{\gamma}$	66	δ	95	ε	85
			$\boldsymbol{\beta} \cup \boldsymbol{\gamma}$			68	$\delta \cup \varepsilon$			130
Correct data	$\boldsymbol{\alpha} - E$	71	$\boldsymbol{\beta} - E$	62	$\boldsymbol{\gamma} - E$	65	$\delta - E$	59	$\varepsilon - E$	63
			$(\boldsymbol{\beta} \cup \boldsymbol{\gamma}) - E$			65	$(\delta \cup \varepsilon) - E$			72
Precision ratio P	$\frac{\boldsymbol{\alpha} - E}{\boldsymbol{\alpha}}$	1.00	$\frac{(\boldsymbol{\beta} \cup \boldsymbol{\gamma}) - E}{\boldsymbol{\beta} \cup \boldsymbol{\gamma}}$			0.96	$\frac{(\delta \cup \varepsilon) - E}{\delta \cup \varepsilon}$			0.55
Recall ratio R	$\frac{\boldsymbol{\alpha} - E}{(\boldsymbol{\alpha} \cup \boldsymbol{\beta} \cup \boldsymbol{\gamma} \cup \delta \cup \varepsilon) - E}$	0.80	$\frac{(\boldsymbol{\beta} \cup \boldsymbol{\gamma}) - E}{(\boldsymbol{\alpha} \cup \boldsymbol{\beta} \cup \boldsymbol{\gamma} \cup \delta \cup \varepsilon) - E}$			0.73	$\frac{(\delta \cup \varepsilon) - E}{(\boldsymbol{\alpha} \cup \boldsymbol{\beta} \cup \boldsymbol{\gamma} \cup \delta \cup \varepsilon) - E}$			0.81
	All Correct Data: $\boldsymbol{\alpha} \bigcup \boldsymbol{\beta} \bigcup \boldsymbol{\gamma} \bigcup \delta \bigcup \varepsilon$ — E = 89									
F Value	$\frac{2 \times P \times R}{P + R}$	0.89	$\frac{2 \times P \times R}{P + R}$			0.83	$\frac{2 \times P \times R}{P + R}$			0.66

Table 2 Result of Experiment 2

	Group α		Group β		Group γ		Group δ		Group ε	
Method	Improved KT-PPA		Original KT-PPA				Brainstorming			
Experience	Beginners		Beginners		Middle Class		Beginners		Middle Class	
Total number of subjects	5		5		5		5		5	
	5		10				10			
Select data (Included errors)	α	83	β	71	γ	76	δ	92	ε	80
			$\beta\cup\gamma$			77	$\delta\cup\varepsilon$			122
Correct data	$\alpha-E$	81	$\beta-E$	70	$\gamma-E$	74	$\delta-E$	54	$\varepsilon-E$	71
			$(\beta\cup\gamma)-E$			74	$(\delta\cup\varepsilon)-E$			75
Precision ratio P	$\frac{\alpha-E}{\alpha}$	0.98	$\frac{(\beta\cup\gamma)-E}{\beta\cup\gamma}$			0.97	$\frac{(\delta\cup\varepsilon)-E}{\delta\cup\varepsilon}$			0.61
Recall ratio R	$\frac{\alpha-E}{(\alpha\cup\beta\cup\gamma\cup\delta\cup\varepsilon)-E}$	0.84	$\frac{(\beta\cup\gamma)-E}{(\alpha\cup\beta\cup\gamma\cup\delta\cup\varepsilon)-E}$			0.77	$\frac{(\delta\cup\varepsilon)-E}{(\alpha\cup\beta\cup\gamma\cup\delta\cup\varepsilon)-E}$			0.78
	All Correct Data: $\alpha\bigcup\beta\bigcup\gamma\bigcup\delta\bigcup\varepsilon-\mathrm{E}=89$									
F Value	$\frac{2\times P\times R}{P+R}$	0.90	$\frac{2\times P\times R}{P+R}$			0.86	$\frac{2\times P\times R}{P+R}$			0.68

Table 3 Result of Experiment 3

	Group α		Group β		Group γ		Group δ		Group ε	
Method	Improved KT-PPA		Original KT-PPA				Brainstorming			
Experience	Beginners		Beginners		Middle Class		Beginners		Middle Class	
Total number of subjects	5		5		5		5		5	
	5		10				10			
Select data (Included errors)	α	142	β	130	γ	132	δ	148	ε	149
			$\beta\cup\gamma$			136	$\delta\cup\varepsilon$			197
Correct data	$\alpha-E$	140	$\beta-E$	126	$\gamma-E$	129	$\delta-E$	107	$\varepsilon-E$	133
			$(\beta\cup\gamma)-E$			129	$(\delta\cup\varepsilon)-E$			140
Precision ratio P	$\frac{\alpha-E}{\alpha}$	0.99	$\frac{(\beta\cup\gamma)-E}{\beta\cup\gamma}$			0.95	$\frac{(\delta\cup\varepsilon)-E}{\delta\cup\varepsilon}$			0.71
Recall ratio R	$\frac{\alpha-E}{(\alpha\cup\beta\cup\gamma\cup\delta\cup\varepsilon)-E}$	0.85	$\frac{(\beta\cup\gamma)-E}{(\alpha\cup\beta\cup\gamma\cup\delta\cup\varepsilon)-E}$			0.79	$\frac{(\delta\cup\varepsilon)-E}{(\alpha\cup\beta\cup\gamma\cup\delta\cup\varepsilon)-E}$			0.85
	All Correct Data: $\alpha\bigcup\beta\bigcup\gamma\bigcup\delta\bigcup\varepsilon-\mathrm{E}=89$									
F Value	$\frac{2\times P\times R}{P+R}$	0.91	$\frac{2\times P\times R}{P+R}$			0.86	$\frac{2\times P\times R}{P+R}$			0.77

Table 4 The number of risks extracted from vulnerable area by Group α

	Problem 1	Problem 2	Problem 3
Correct Data $\alpha-E$	71 (100%)	81 (100%)	140 (100%)
the vulnerable areas (Ratio of correct data)	58 (82%)	69 (85%)	115 (82%)
The extended vulnerable areas	13 (18%)	12 (15%)	25 (18%)

VI. Evaluation of Experimental results

(1) It is backing of the hypothetical formation of "the risk identification capability improved more with increased work experience."

We experimented under the hypothesis of "the risk identification capability improved more with increased work experience." However, we did not have the data that this hypothesis was formed till now. The documents, which proved this quantitatively, were not found even when references were investigated thoroughly. However, through this experiment, we got the data, which supported the conclusion of this hypothesis (a law learned by experience). When the experiment results in Table1-3 are checked, in the result (Table1) of experiment 1, the correct risk data extracted by original KT-PPA, there are 65 middle class subjects against 62 beginners. In the correct risk data extracted by brainstorming, there are 63 middle class subjects against 59 beginners. Again in the result (Table2) of experiment 2, the correct risk data extracted by original KT-PPA, there are 74 middle class subjects against 70 beginners. In the correct risk data extracted by brainstorming, there are 71 middle class subjects against 54 beginners. And in the result (Table3) of experiment 3, the correct risk data extracted by original KT-PPA, there are 129 middle class subjects against 126 beginners. In the correct risk data extracted by brainstorming, there are 133 middle class subjects against 107 beginners. From this, persons of middle class extract the correct risk data than the beginner without exception. In other words the conclusion (a hypothesis) that "risk identification improves as work experience increases" is supported.

(2) Comparison from the number of extracted correct data.

By the number of risks (correct data) investigated as a result of analysis Group α win all the other groups. Though the experience in actual business of risk management is almost the same as Group β or δ, they were able to extract much more risks. Again though the experiences in actual business of risk management of

Group α ran short rather than Group γ or ε, they were able to investigate more or almost the same risks. From this it was proved that even the persons with less risk management experience could investigate more risks with improved KT-PPA compared to original KT-PPA or brainstorming. Again it was confirmed that this fact do not change with 15 minutes of experiments 1 and 2 or with 30 minutes of experiment 3. Thereby, improved KT-PPA had the low dependence on time, and it was checked that it could effectively investigate the risks even also in the limited time.

(3) Comparison from precision ratio.

It was checked that the high numerical value had been acquired in recall with improved KT-PPA and original KT-PPA. This indicates that the information obtained by investigating risks with improved KT-PPA and original KT-PPA, irrelevant risk information is not included. This fact shows that the subjects had trouble in investigating the risks in important domains and it is the result of applying KT-PPA. Further it was checked that many things unrelated to risks were contained in the information acquired by the group who used brainstorming. Especially the Group δ with little experience had many unrelated information. From this why information completely unrelated to risks has been included in brainstorming is caused by rule [3] of the 4 rules. Therefore, if brainstorming is used at all, it is thought that it is difficult to avoid from this problem.

(4) Comparison from recall ration.

It was checked that the high numerical value had been acquired in recall with improved KT-PPA and brainstorming. This shows that risks of investigated by these methods had few leaks.

The high numerical value acquired by the improved KT-PPA is because of inclusion of important domain, which can be considered because of wider risk search space than original KT-PPA. Actually by the upper class of risk management, risks probed by each group the number of cases (number of types) were checked. Although individual differences are there, the number of cases (the number of kinds) of risk investigated by Group α with improved KT-PPA, included all the risks investigated by Group β and γ. This can be considered that that the risks search space was narrowed has influenced when the subject investigated the risks along the important domains.

On the other hand in brainstorming, that there is no restriction by the risks search space for higher numerical values.

Actually when the investigated risks by Group δ and ε of brainstorming were checked, in addition to risks investigated by Group α, [risks extracted first time by Group δ, and not by Group α], and [risks extracted first time by Group ε, and not by Group α,] were included. [The fact that existence of risks extracted by Group ε, and not by Group δ, brainstorming is the method where experience means a lot.] Brainstorming being reverse to KT-PPA is effective in enlarging the search space of the risks, and it is thought to be able to extract the risks that were not possible with other methods.

By the way, since brainstorming is strong for the element (a posteriori), the risks extracted by this method also have characteristic. Again the risks extracted by the beginners Group δ had the features of being extracted from the viewpoint more nearly general-purpose than a special viewpoint. The exact example is shown in Fig. 12. On the other hand the middle class Group ε had the features of risks extraction more by special viewpoint than general-purpose. The exact example is shown in Fig. 13.

- At the time of a work request, may have given wrong coding of application for check so the work of grammatical check may become useless.
- Thunder may fall during work and a server may break.
- By having worked without contacting the person in charge, may be scolded by the person in charge after the end of work.

Fig.12 Examples of risks which beginner's class δ alone identified through brainstorming.

- A configuration file may be damaged when rebooting software.
- When rebooting software, it may become disk full by system log being written on the disk in large quantities, and the next work may not be able to be performed.
- When rebooting a server, failure may occur with a hard disk and the server may not start.

Fig.13 Examples of risks which middle class group ε alone identified through brainstorming.

Risk in these examples is applicable to below.

[R7] The point where the possibility to occur is low, but a serious loss occurs when it happens.

- The point where the possibility to occur is low, but a slight loss occurs when it happens.

Moreover, about the vulnerable area at the time of investigating risks, we interviewed the Group α which uses the improved KT-PPA method. As a result, for all problems in addition to risks extraction form the existing vulnerable area, there were new risks extracted from extended domains, and the validity of the methods, which were newly proposed were able to check. The result is shown in Table 4.

(5) Comparison from F value

We consider a meaning of higher ***F*** value. As stated previously, formula (3) can show ***F*** value.

$$F = \frac{2 \times P \times R}{P + R} \qquad (3)$$

Now, it will become formula (4) if formula (1) and formula (2) are substituted for formula (3), respectively.

$$R = \frac{\mathrm{C}}{A} \qquad (1)$$

$$P = \frac{\mathrm{C}}{\mathrm{B}} \qquad (2)$$

$$F = \frac{2C}{A + B} \qquad (4)$$

From this formula (4), the following things can be said about high ***F*** value.

When the value of the set ***A*** of the risk that should be identified [correct data], and the set ***B*** of the data generated by method ***X*** are constant, which mean that the ratio of the common part of ***A*** and ***B*** are high. In other words the values of ***P*** and ***R*** are high at the same time and means that it is an ideal technique. In order to understand this intuitively, an example with high ***F*** value is shown in Fig. 14, and an example with low ***F*** value is shown in Fig. 15.

In this experiment, the F value by improved .KT-PPA method was 0.89 in experiment 1, 0.90 in experiment 2, and 0.91 in experiment 3 and was confirmed to have acquired high value. Since the F value is high by improved KT-PPA method, it means both precision ratio and recall ratio are high. And it means KT-PPA is the ideal method for risks identifications.

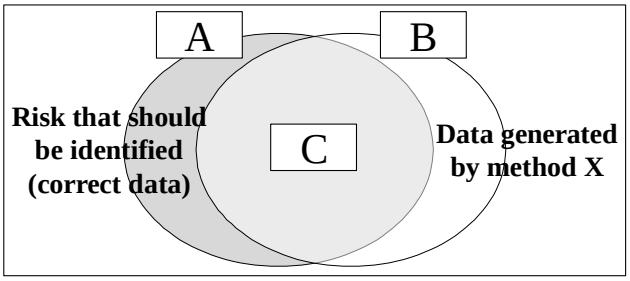

Fig.14 A Venn diagram in case of high score F-value.

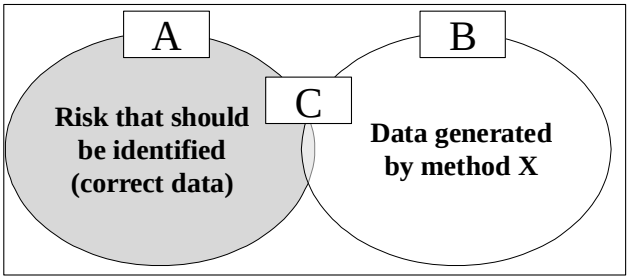

Fig.15 A Venn diagram in case of low score F-value.

(6) Evaluation Risks Identification Methods

By experiment, we could check the following things about the method which improved KT-PPA

- By using the improved KT-PPA, as a result of comparing the number of investigated risks, even the persons with little experience of risk management were able to investigate risks effectively rather than persons with deep knowledge of risk management using original KT-PPA or brainstorming.
- As a result of comparing precision ratio, it was confirmed to investigate risks more correctly with improved KT-PPA, and original KT-PPA methods than with brainstorming.
- As a result of comparing recall ratio, it was confirmed that the risk extraction leakage by brainstorming and improved KT-PPA was less than original KT-PPA.
- As a result of comparing F value, it was confirmed that improved KT-PPA method is ideal with better functions than original KT-PPA and brainstorming for risks identification.

Moreover, in this experiment, the sorting of risks and irrelevant risks information (work of STEP4 as enforcement

procedure) was done by upper class of risk management. In this work the more risks and irrelevant risk information, the more time and efforts are required.

Also there are possibilities of making work mistakes.

Therefore, the lesser is the irrelevant risk information, the higher is the quality of sorting risks and lesser the cost of risks sorting work. Now in the actual project, the members who extracted risks do the sorting work by themselves. Based on this, the following things can be described from the checked results.

- Evaluation of brainstorming

When the investigated risks results are checked and improved and original KT-PPA are compared, the individual capability, technology and experience have a higher dependence. Therefore, it is difficult for beginners. The recall ratio is high, so the leakages of correct risks are less. And it is the appropriate method of risks investigation. But since the precision ratio is lower so correct risks investigations are difficult. And since in the investigated risks data, there is much many information not related to risks, the sorting work takes time. Therefore, the work time of investigating risks becomes longer (high cost) as compared with improved KT-PPA and original KT-PPA. Specially, when beginners do the sorting work, at times it is difficult to distinguish between risks and non-related risks information.

Therefore, it is not suitable for beginners who have to identify risks within short period of time.

- Evaluation of Original KT-PPA

When the results of risks investigations are checked, compared with brainstorming, the individual's capabilities, technology, and experience levels are low.

Therefore, it is easy to use for beginners. The precision ratio is high, so correct risks investigations can be done. Therefore, the efforts required distinguishing between risks and non-related risks information are less than brainstorming. And the risks investigation work time becomes less as compared with brainstorming. But since the recall ratio is low, leakage occur in correct risks extractions. Since there are deficiencies in extraction of risks, there are chances to overlook the risks with potential problems. Therefore there are possibilities of harming reliability of risk management remarkably in the future.

Therefore, it is not suitable for beginners who have to identify risks within short period of time.

- Evaluation for Improved KT-PPA

When the risks extracted results are checked, compared with brainstorming, the individual's capabilities, technology, and experience levels are low. Therefore, it is easy to use by beginners. Further by proposing the new index [R7], and enlarging the domain of risks search, much more risks can be extracted compared to original KT-PPA, and since precision ratio is higher, correct risks can be extracted. For this reason, the efforts to distinguish between risks and non-related risks information are less compared to brainstorming. Therefore, the work time to extract risks is less (lower cost) than brainstorming. Again the recall ratio is high, so the leakage of correct risks extraction is less.

Therefore, with the improved KT-PPA method, the beginners can extract the risks data alone within limited time, and sort correctly.

VII. Conclusions

In this paper, we took up the risk management of a project and above all risk identification, and showed a concrete implementation method based on the improved Kepner-Tregoe Program. In this paper, we proposed a concrete implementation method of risk identification based on the improved Kepner-Tregoe Program, and showed that the method is effective. We performed laboratory experiments on risk identification using the proposed method. Moreover, we compared the proposed method with the widely known methods based on the brainstorming and the original Kepner-Tregoe Program. As a result, we confirmed that the method based on the improved Kepner-Tregoe Program is more effective and correct than the method based on brainstorming and the original Kepner-Tregoe Program in terms of generality and efficiency.

From the result of experiment check, especially in respect of precision ratio found that improved KT-PPA is more advanced than brainstorming and original KT-PPA. From the result of experiment check, especially in respect of recall ratio found that improved KT-PPA is more advanced than original KT-PPA. This showed that improved KT-PPA method is superior to original KT-PPA. This showed that improved KT-PPA method can serve as a tool more powerful than brainstorming for general-purpose methods for risk identification.

In addition, there are various methods of operation in brainstorming. For example, the brainstorming based on the proposal of Smith et al [15], from the viewpoint of schedule may have the capability to extract more risks than normal brainstorming method. But it is difficult to resolve the problem of [The brainstorming is easy to depend on capability, technology, and experience of the members who take part in the project] when using brainstorming. Moreover, if brainstorming is extracting risks protecting rule of the 4 rules [3], it is difficult to avoid the mixing of risks with non-related risks data. Therefore, the authors suggested in this paper that the correctness of risks identification by KT-PPA is more advanced than brainstorming.

However, as described in Section 2, there are no absolute techniques for risks identification. You should use improved KT-PPA method by understanding the merits / demerit. This time even in the project by experimenting with members of low technical knowledge problem, the validity of improved KT-PPA method was confirmed. However above assuming it for general-purpose use, about the strong problems in special domains, it is difficult to extract risks in these vulnerable areas.

For example, by the anti-handicap measure project that occurred by software of complicated configuration, an interview of the person who developed software and the checklist from a past example may investigate risks effectively. Moreover, the project can consider narrowing the search domain which probes a risk by showing the vulnerable areas according to an issue even if it is the problem that the dependence to a technical field is low. For example, when the worker extracts risks in their experienced fields, brainstorming collects information irrespective of risks, so brainstorming can collect more risks information. About this point, we will consider in future research about the good/bad points of improved KT-PPA and make clearer.

In the end, by analysis of the experiment results, we want to check about new problems.

- People show individual differences in the mode of expression of risks extraction.

Although Kino [25] is taking care of precedence research about this matter, there is till room for study. About this, future studies will be made and deep studies will be made about this matter with support of the risk identification.

APPENDIX

[About the Card BS Method]

Takahashi [23] who is the developer of the card BS method shows the general work sequence of the card BS method as follows.

[Advance Preparations]

(1) Decide the leader.

(2) Surround the desk in a circle and take seat and have a card.

(3) Discuss a theme.

[Public Performance]

(1) Each person consider individually.

(2) Arrange the cards by announcing the order.

(3) Ask questions on way-of-thinking ideas, or add your ideas.

(4) Carry out the individual way of thinking again.

(5) Again arrange the cards by announcing the order.

(6) Repeat the individual way of thinking, and arranging cards in order till the time limit hereafter.

(7) Evaluate cards and summarize.

This time performed the card BS method individually. Therefore actual work this time shown by Takahashi is applicable for individual use. In the card BS method, a new rule of "wide way of thinking" which is not in the brainstorming method is added. The "wide way of thinking" is to express the theme from various angles as far as possible. However, in this experiment we do not use "wide way of thinking". In other words, other than the things that the cards were used and were made possible for use by individual, it is the same as the general brainstorming method.

ACKNOWLEDGMENT

This research and development is done by obtaining consent of Kepner-Tregoe group of Japan branch.

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