Verification of Risk Countermeasures Regarding Expressway Traffic Control System Based on Creative Risk Management Approach

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Abstract--**The conventional risk management based on dealing with the incidents occurred in the past mainly focuses on preventing the similar incidents against the past incidents. In the meantime, it is true that there are a lot of comments saying "beyond the scope of the assumption" or "unknown accident we've never seen before" after the incidents occurred. Therefore, in this paper, we propose "Risk Creative Approach (RCA)" to prevent risks after creating the risk generating mechanism based on the way of realizing risks intentionally, which comes from "Sabotage Analysis (SA)" benefitting from game theory's standpoint. We introduced RCA to the proposed plan(we already considered) regarding "Backup System (BUS) "of "Expressway Traffic Control System (ETCS)" at Metropolitan Expressway Company(MEX) and tried to analyze and verify it. In consequence, we reaped the viable risk countermeasures including proposed measures against tsunami. Proposed countermeasures were proposed before "The great eastern Japan earthquake on 11th of March 2011". And we conducted a review of previous plan by applying proposed risk countermeasures. What this case example makes clear is that we confirmed the effectiveness of RCA (proposed method).**

I. INTRODUCTION

Most of the existing "Risk Management (RM)" approach is based on the validation of the past. Therefore, the existing RM mainly focuses on the preventive measures to eliminate the bottom cause of the accident by gathering information about the similar accidents in the past and identifying the causes of their outbreak. That is, the principle about "studying from the failures in the past" becomes the basic premise. That's why RM based on the validation of the past looks like the minimum requirement for RM activities and is fundamental basis of RM. On the other hand, it is a fact that many people concerned say, "this accident was unexpected and new type" after the outbreak of accidents. The reason of such comments is that no accidents or incidents can be 100 % same with those in the past, and the people in charge who faced the risk interpreted that the accident was an unexpected one. However, if they say the risk was beyond expectations in spite of the fact that they experienced similar accidents in the past, it's sure that they don't have enough sensitivity against risk, largely because of lack of imagination against risks. Another type of unexpected risks to note here is truly unknown risk which has never been encountered before. For example, recently, net crimes [3] like leaking private information through shopping on the Internet or SNS are reported frequently. In this kind of situation, existing RM like dealing with the incidents occurred in the past is not very effective. Most of net crimes are the typical unprecedented risks we couldn't predict and failed to deal with because of our fixed thinking based on our past experience [13]. Therefore, in this paper, we want to propose "Creative Risk Management Approach (CRMA)" as the effective RM method coping with both "resolving the lack of imagination against risks" and "designing the creative measures against unknown risks in the future". We applied CRMA to the planning regarding "Back Up System(BUS)" of the traffic control system at Metropolitan Expressway Company Limited (we call "MEX" from here) and assessed the efficacy of CRMA through the analysis and verification of the result in this paper. The subject at MEX is one of the important themes related to the IT-based risks and need the ability to predict the change of environment in the near future. Therefore, this subject is considered to be best suited for applying CRMA.

II. BACK GROUND OF THE STUDY

We developed this method of CRMA, studying "Anticipatory Failure Determination (AFD)" [10] as a reference. AFD is one of "Risk Analysis (RA)" techniques derived from TRIZ [11]. By the way, what is TRIZ? The letters T.R.I.Z is an English acronym from the Russian words "*Teoriya Resheniya Izobretatelskikh Zadatch* "which are translated as Theory of the Solution of Inventive Problems. Originally, TRIZ is a term of management technology, which had been developed by Genrich Altshuller who used to be a patent analyst in former USSR from 1946 to 1985[9, 4]. He had organized the basic theory and unique techniques including "40 Inventive Principles" through the analysis regarding the huge patents data. TRIZ is mainly applied to engineering system as an inventive problem solving method. One of the most remarkable features of AFD is to create the ideas to realize risks (failure and accident), utilizing "Reverse Thinking" coming from the principle #13 "The Other Way Around" in 40 Inventive Principles in TRIZ. Creating ideas to realize risks, AFD requires us to make "Risk Scenario (RS)" which could be occurred and to consider the measures to avoid latent risks in near future.

As just described, AFD is one of the unique RM techniques. AFD was developed by Ideation International in USA, one of TRIZ consulting firms. AFD is also called"Sabotage Analysis". Because AFD requires us to create the bad idea connected to incident (risk) from the standpoint of terrorists. And so, in this study, we focused attention on "Terrorist-oriented Thinking=Reverse Thinking". However, we decided not to apply AFD's complicated

procedure and TRIZ techniques in this study. It's because these techniques in TRIZ are very complicated and hard to use in practice [15]. Although "Reverse Thinking" requires an opposite direction of approach against the existing RM based on validation of the past, we realized that CRMA was fairly similar with "Game Theory (GT)". Because, basic thinking of GT is to develop strategy for the business, by assuming the other person's standpoint [8] and making RS from the central player's standpoint, and to propose measures to avoid RS. In this study, "the other person's standpoint" and "strategy for business" in GT are replaced with "those who cause accidents (or incidents)" and "measures to avoid RS" in CRMA.

Incidentally, the two affirmations in the field of RM as shown in Fig 1 are traditionally opposed to each other, but they coexist in the actual RM.

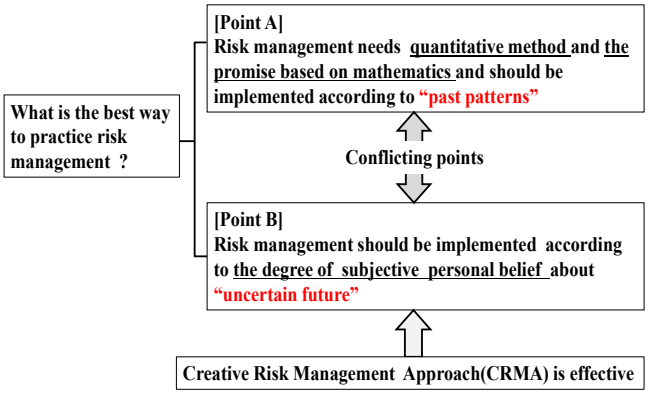


Fig.1 Two points about risk management

A large number of existing RM with the validation of the past try to approach the risks from the probability based on "Point A". If they practice "Point A" in any case, RM maintains objectivity. For example, such risks as financial asset risk and credit risk are quantitatively measurable. However, it's very hard to measure the degree of risk quantitatively in other operational risk areas (on the daily business operation). Therefore, KYT (is an English acronym for the Japanese words "**K**iken **Y**ochi **T**raining" meaning "Hazard Predictive Training") and KYK (is an English acronym for the Japanese words "**K**iken **Y**ochi **K**atsudo" which mean "Hazard Predictive Activities") are recognized as popular existing RM approaches, in particular, at work sites in manufacturing and construction industries in Japan [5], for realizing zero disaster, instead of RM approach to measure the degree of risk objectivity. It's because KYK and KYT are easily understandable and are basically based on learning from the past incidents by taking those seriously with a sense of fear. So, KYK and KYT mainly focus on raising awareness of RM. Meanwhile, CRMA is an approach based on respecting subjective personal belief about an uncertain future in terms of "Point B".

III. FEATURES OF CREATIVE RISK MANAGEMENT APPROACH

As I have described previously (in Chapter I), CRMA is effective in strengthening imagination on the risks which might occur in future as CRMA is a future-oriented thinking. The other benefit of CRMA is to create the unknown risks of the future, free from what happened in the past. That is to say, if we create the unknown risks of the future, making the mechanism of unknown risks clear, it's possible to consider their preventive measures flexibly. Authors focused attention on these unique features and developed practical procedure (See Table1 in Chapter IV) with several "Work Sheets (WS)" (See a case example in Chapter V) of CRMA. And, in order to create unknown risks without fixed thinking, what we utilized "Functional Diagram" in "Value Engineering (VE)" is one of the unique features of CRMA. VE is originally a management technique to define functions regarding existing products, to create ideas based on "Function-oriented Thinking", to eliminate wasteful cost and finally reach highly-valued products having good balance between function and cost [12]. In this paper (this time), we tried to convert "Each Cause of Losses (Risks)" to "(Harmful) Functions" and utilized them to create ideas for realizing harmful functions. The details will be explained in the next chapter (See Fig.4).

By the way, the way of thinking in KYT and KYK we mentioned at chapter II is based on "How risks occurred?" Therefore, we have to search more effective methods with the concept for breaking down stereotypes than conventional RM approach like KYT/KYK. If we try to ensure the objectivity of RM based on "Point A", we think that "The Study of Failure (SF)" [6] is more effective and objective against such a background as a new RM approach. SF developed by Dr. Yotaro Hatamura is called "SHIPPAIGAKU" [7] in Japanese. This method is based on the concept of "Learning from the Failure" in past times. If we secure the effective proposed measures against the risks we face through analogy thinking based on a lot of failure cases in past times, which is called SF, we approve of the effectiveness of SF as a new RM approach. However, even if we can find out the similar cases against our risks by utilizing SF, in order to make effective measures against unknown risks, studying SF, we need to master future-oriented thinking with creativity to grasp near future's trend as we mentioned in Chapter I. That is, even if we need to learn similar case examples in the past, it is imperative that team members of RM require imagination and creative ability. That's why future-oriented thinking is useful and effective in any RM activities. Therefore, we have to consider another method as complementary to not only KYT/ KYK but also SF. As we have seen, CRMA is based on future-oriented thinking to create measures against unknown risks. Hence, CRMA is an appropriate complementary method to both KYT /KYK and SF. Future-oriented thinking of CRMA is based on "How we create risks?". This question is inner nature of "Reverse Thinking" regarding CRMA (See Fig.2).

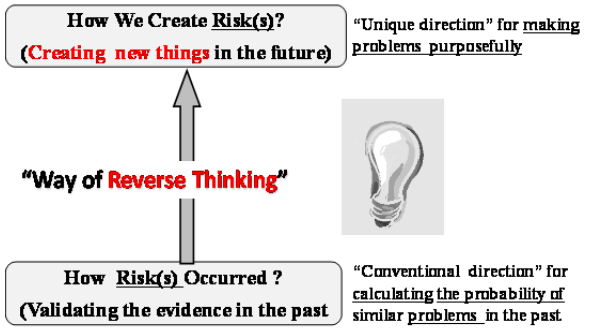


Fig.2 Way of reverse thinking

	Conventional RMA		Proposed Method(CRMA)
Way of thinking	Past inspection thinking	⇔	Future-oriented thinking
Key to thinking	How risk(s) occurred?	⇔	How we create risk(s)?
Feature of method	Failure data related to past accidents	⇔	Reality of ideas to realize future risks
Proposed measures	In general, conventional measures	⇔	In general, innovative measures (we've never practice)
Main field of application	Environmental variation is not so changeable Ex. Site work etc.	⇔	Environmental variation is drastic Ex. New project theme etc.

Fig.3 Features of both conventional and proposed method

As just described, the purpose of proposed method of CRMA is not to find the failure phenomenon from past accidents, but more importantly to define them as "a kind of matters to be realized". After we define them, we have to create the realized ways by utilizing "Functional Analysis (FA)"in VE. FA is a unique technique in the procedure of CRMA (See Table1 at chapter Ⅳ)". This is the most significant characteristic of CRMA as previously explained. In short, Future-oriented RMA based on "Reverse Thinking" is very effective against unknown risk(s). This is because conventional RMA based on "Past Inspection Thinking" does not deal with unknown risk(s) effectively. The Fig.3 shows some features of both conventional (in particular KYT/KYK) and proposed method (CRMA).

IV. PRACTICAL PROCEDURE OF PROPOSED METHOD (CRMA)

We want to consider both uniqueness and effectiveness about CRMA through a real case example to have been applied at Metropolitan Expressway Company in the next chapter. Before a case example, we want to introduce the practical procedure of CRMA. As shown in Table1, the practical procedure mainly consists of three "Basic Steps", namely, "Risk Analysis", "Idea Generation For Realizing Risks" and "Planning Proposed Measures Against Risks". Each "Basic Step" has several "Job Steps". We practiced CRMA through a case example in accordance with the eight "Job Steps (SETP 1 through STEP8)". By the way, the point to be most emphasized on the eight "Job Steps" is that CRMA's procedure is developed in accordance with the principle of "Design Thinking". That is to say, a special feature of this procedure is that it is designed as a procedure to be practiced by shifting between "Convergent Thinking" and "Divergent Thinking", namely "Analysis and Synthesis" [2]. The existing RM, in most cases, is based almost solely on convergent thinking for reaching a single solution by analyzing the past information. In order to predict risk(s) in future, however, it is necessary, like CRMA's procedure, to prepare the step(s) to practice divergent thinking based on synthesis. Moreover, this method is characterized by practicing "Design Thinking" from risk-maker's standpoint in STEP3 through STEP7 by applying the basic concept of GT.

TABLE 1. FEATURES REGARDING PRACTICAL PROCEDURE OF PROPOSED METHOD

Basic Step	Job Step	Design Thinking	Rough Outline of Each Step
Risk Analysis	STEP1:Collecting Information About A Subject Matter	Analysis (Convergent thinking)	To achieve a mastery of a subject matter
	STEP2:Organization of Risk Condition	Analysis (Convergent thinking)	To put risk factors in order based on "cause and effect analysis"
	STEP3:Making Harmful Function Diagram	Analysis (Convergent thinking)	To make harmful function diagram by defining "causes" bring about risk(s) as "harmful functions"
	STEP4:Checking Weakness Zones of Subject Matter	Analysis (Convergent thinking)	To explore the weakness zones in subject matter
Idea Generation For Realizing Risks	STEP5:Harmful Function-Oriented Idea Generation	Synthesis (Divergent thinking)	To create a lot of ideas to actualize risk(s) based on harmful function-oriented thinking
	STEP6:Grasping Dangerous Resources For Causing Risks	Analysis (Convergent thinking)	To evaluate the ideas we created from the standpoint of occurrence frequency about hazardous resources
Planning Proposed Measures Against Risks	STEP7:Organizing Scenarios For Realizing Risks	Synthesis⇒ Evaluation (Divergent⇒Convergent)	To make risk scenarios(s) to actualize risk(s) by utilizing selected ideas
	STEP8:Planning Proposed Measures to Avoid Risk Scenarios	Analysis⇒Synthesis⇒ Evaluation (Divergent⇒Convergent)	To make countermeasures to avoid risk(s) by learning the mechanism(s) boiling up risk(s) from risk scenarios(s)

Steps from risk-maker (criminal)'s standpoint Steps from risk-avoider's or spectator's standpoint

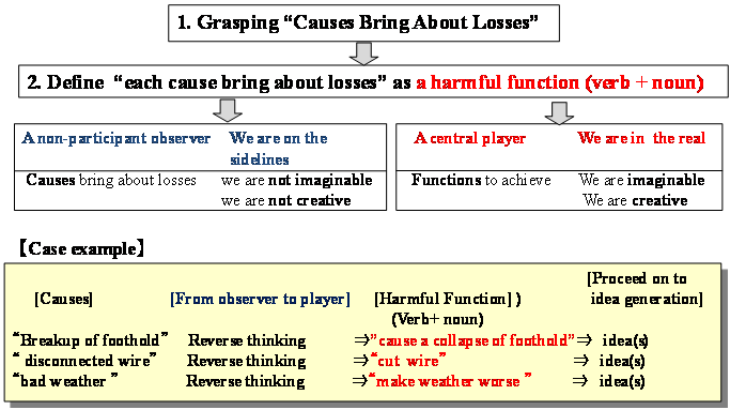


Fig.4. Utility of function definition technique

In particular, both STEP3 and STEP5 are very unique STEP focusing on "Functional Approach" based on "Function-oriented Thinking" in VE. We utilized function definition techniques at STEP3.

Specifically, interpreting "Causes of Losses" as "Harmful Functions to Achieve", we tried to define harmful functions by "Verb and Noun" format. And then, we tried to create new things (ideas) to realize defined harmful functions at STEP5. STEP3 through STEP5, it's possible to move the risk factors from non-participant observer to person(s) in charge of the risk management activity logically by transforming risk factors from usual risk items into functions. To put it more concretely, putting risk factors to the person(s) in charge means the improvement of his/their imagination ability in the process of coming up risks. Fig.4 shows utility of function definition technique in VE.

In this way, the most significant characteristic of "Functional Approach" in VE is to convert "each cause of Losses" which is no more than objective facts to "Harmful Function" to be realized, in other words, to make a total shift of thinking to the standpoint of the person(s) in charge of RM. Consequently, "Functional Approach" is a technique to strengthen the subjective personal belief based on "Point B (SeeFig.1)".

V. A CASE EXAMPLE REGARDING "TRAFFIC CONTROL SYSTEM AT THE METROPOLITAN EXPRESSWAY"

A. What is traffic control system of expressways?

Traffic control system in Metropolitan Expressway (MEX) mainly consists of "Information Gathering", "Information Service" and "Information Processing". Fig.5 shows "Traffic control system" systematically and visually. MEX found out the necessity of the "Back Up System (BUS)" for improving the reliability of traffic control system and sustaining its business activity. The committee members including some outside experts, after a broad range of verifications of the plans made on all the anticipated risks, finally concluded in 2005 to construct a new building and to install the BUS at a site different from where the present main system was located. However, the plan for establishing BUS in a new building had the following secondary issues to be considered.

[Envisioned secondary problems]

1. Too large scale of investment (Nearly 1.2 million dollars investment)
2. High running cost
3. Legal problem as the project was not officially approved by the related agencies.

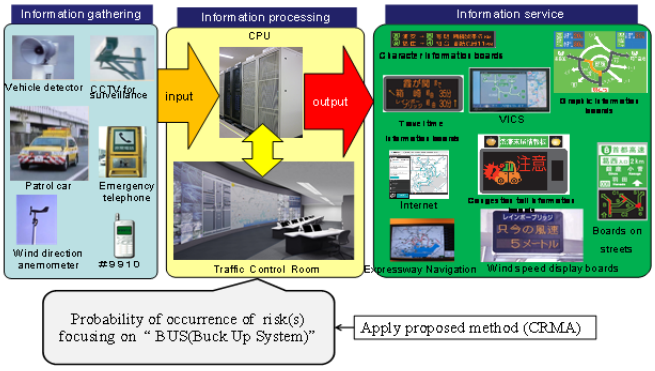


Fig.5.Traffic control system in Metropolitan Expressway

In fact, the assumed issues for MEX was not only the financial and budget risks but also the risk in the event of disasters and the business opportunity risk (if the reasoning of new building construction was not clear enough). It was decided, therefore, to reexamine the BUS building plan by utilizing CRMA.

B. A case example about the traffic control system (including BUS)

STEP1: Collecting Information about a Subject Matter (Analysis Stage)

A "Subject Matter(SM)"for "Risk Management" should be defined. SM showing in this paper is "The traffic control system of Metropolitan Expressway". In particular, we kept in mind "BUS" as one of measures regarding information security. Table2 shows some of the advantages and disadvantages about the current traffic control system from

the perspective of the whole system level. This time, we select four lodgments of traffic control system with four system components as SM for Risk Management.
According to Table 2, while this location has an advantage of immediate emergency response, security is not so good and the danger of terror attacks is pointed out.

STEP2: Organization of Risk Condition (Analysis Stage)

We need to organize the situation about the "Envisioned Risks (Failures)", which might occur in the near future, at this step. To put it more concretely, we have to clarify the relationship between losses (bad results) and causes brought about by them based on "Cause-Effect Logic" to the best of our ability. The work at this step is essentially the same as conventional RMA. In this case, keeping in mind the results of previous step (See Table2), especially factors of disadvantages, we tried to organize the risk condition based on cause-effects logic (See Table3). As the result, we extracted main six losses.

STEP3: Making Harmful Function Diagram (Analysis Stage)

We tried to make the "Harmful Function Diagram" showing the relationship between "the final loss (top harmful function) and "each cause brought about by each loss (each harmful function)". The diagram must be drawn based on "Table of cause -effect about risks (See table3)" we sorted out at the previous step.

TABLE 2. ADVANTAGES AND DISADVANTAGES ABOUT CURRENT TRAFFIC CONTROL SYSTEM (PORTION)

Information about a Subject Matter	
Advantages	Disadvantages
● Immediate emergency response can be done since many specialists in various disciplines are located in the same office.	● The building is not "quake-resistant." Therefore, it is highly possible to have damages to the equipments when there is a turbulence by an earthquake.
● Since buildings were recently renovated, equipments such as air-conditioning, lighting, etc. are new.	● Security is not perfect since there are many exits and entrances and many unspecified people can come in and out.
● Good location with good transportation access. ● Furthermore, this is the place where people get together in an emergency.	● Since the location is close to a national central function, it may be a target of a terror attack.
—	● Fire possibility is high since many people are working in the building.
—	● The building may face fire spreading since it is located in dense area.

TABLE 3. TABLE OF CAUSE-EFFECTS ABOUT RISKS (PORTION)

To sort out Risk Situation (Cause-Effects about Risks)		
Major losses (assumed defects)		The cause for losses
1	● The traffic information is not provided for a long time.	1.Equipments fall by a big earthquake 2.Fire 3.System failure 4.Terrorism 5.Flood 6.Communication blackout
2	● Electric Tall Collection Systems (ETC) is stopped for a long time.	1.Equipments fall by a big earthquake.2.Fire 3.System failure 4.Terrorism 5.Flood 6.Communication blackout
3	● The ETC information is leaked.	1.A hacker's invasion 2.Loss of data since they are taking out 3.Data transmitting error 4.Management error of output data
4	● ETC data is lost.	1.Equipment falls by a big earthquake 2.Fire 3.System failure 4.Terrorism 5.Flood 6.Communication blackout
5	● Stopping the operation at the time of emergency.	1.Delay of communication 2.Design error 3.Operation error 4.Management error
6	● Criticism of wasting money by mass media	1.Not normally used 2.Controversial design

To put it more concretely, in order to organize all defined functions after interpreting each cause as each harmful function by defining harmful functions based on "Verb and Noun" format, we tried to make that diagram (See Fig.6) based on "Purpose and Means Logic" [1], which is one of the techniques in VE called FA. However, as VE practitioners know, FA usually focuses on useful function (it's called just function in VE). But, in this case, we focused on harmful function. As previously indicated, we tried to define a cause as a (harmful) function to be realized. FA at this step gives team members the unique but logical way of thinking we had almost never experienced before for chasing "Top Harmful Function (Final Loss)" from criminal's standpoint. In this case, we finally reached "A company is forced to get dissolved "as "Top Harmful Function" by utilizing "Purpose and Means Logic".

STEP4: Checking Weak areas of Subject matter (Analysis Stage)

At step4, distinguishing weak areas from others in SM, we have to define weak areas as "the big triggers" to bring about the final loss. On the other hand, well-protected areas, which are stable against causes brought about by the serious losses, exist in it, too. Especially, the areas we've never made an inspection before, which might be weak areas. This is because these areas have never caused serious accidents for a long time, even without precaution measures. Of course, there are many other weak areas as "the big triggers" against risks. In this case, we drew attention to "Zone that the flow of material, energy or information is getting centered on" as one of weak areas. Therefore, we selected CPU of traffic control system as a weak area. Star sign on harmful function diagram (See Fig.6) is harmful function deeply connected to selected weak area.

STEP5: Harmful Function-Oriented Idea Generation (Creation Stage)

We created a lot of ideas to realize target harmful functions as broad as possible, with focusing on selected harmful functions connected to weak area as the big triggers" against risks, based on "Function-oriented thinking" in VE. In order to break free from fixed thinking based on our limited experience and knowledge in past times, we tried to move "Normal Site" in VE activities to "Reverse Site" in Subversive activities. Table4 shows some ideas we created at one of selected harmful functions.

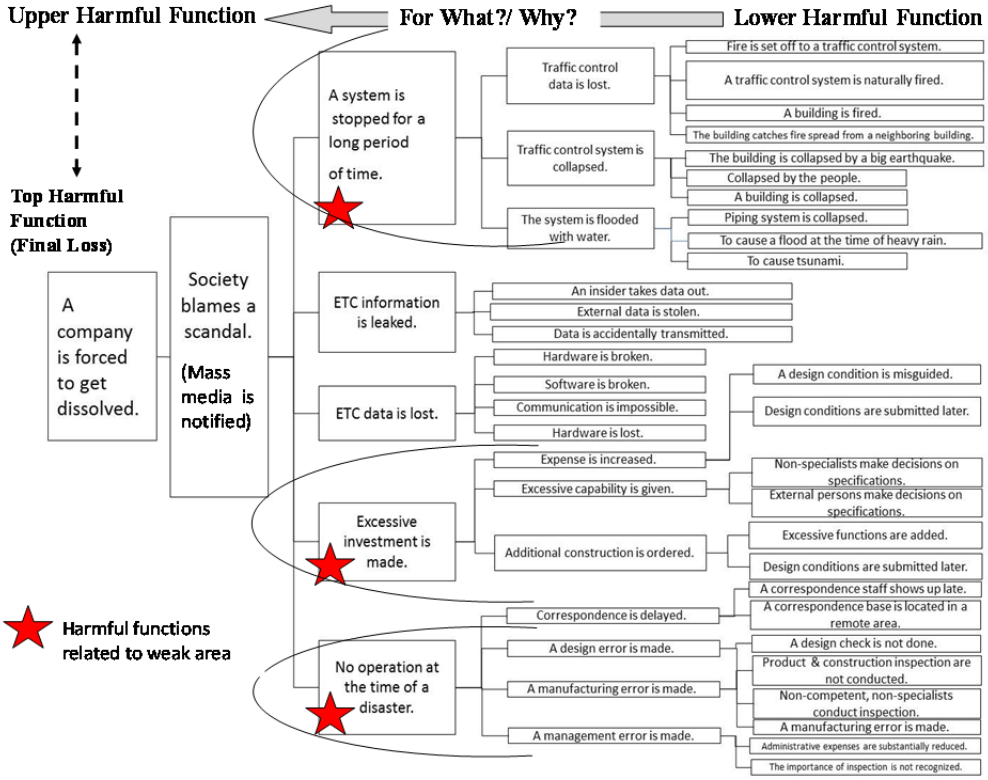


Fig.6. Harmful function diagram about traffic control system

TABLE 4. IDEA GENERATION BASED ON SELECTED HARMFUL FUNCTIONS (PORTION)

Selected harmful function deeply connected to weak area (with star sign on the diagram) [A traffic control system is stopped for a long period of time.]	
Lower level harmful functions related to selected harmful function	Ideas to realize each harmful Function
Fire is set off to a traffic control system.	1.To brainwash an employee to start a fire with ignitions. 2.To get inside the company pretending as if a subcontractor to start a fire.-------
A building is ignited.	1.To make a fire detector unworkable. 2.To fill up the fire extinguisher with explosive gas instead of Co_2 . ----------
The building is destroyed by the people.	1.To stop the air conditioning system to fail the systems due to the overheating of the equipments. 2.To place an explosive in the BUS to destroy the equipments. ----------
A building is collapsed.	1.To drive a vehicle loaded with combustibles into the building from a main highway next to it. 2.To crush an airplane with combustibles.

STEP6: Grasping Dangerous Resources for Causing Risks (Creation Stage)

In order to evaluate the possibility to realize the created ideas, we tried to grasp the dangerous resources to be useful for the outbreak of risks. In addition, managerial resources sometimes fall within the range of dangerous resources, of which four factors (Man, Material, Money, and Information) must be considered the most dangerous. These four factors are defined as highly-valued resources contributing to the efficiency of business administration under normal conditions. But then, "Man" could evolve into a very dangerous resource more frequently. That's why human-being become a hot bed of human error. Organizing the necessity of conditions to realize each idea, evaluating whether the resources on these conditions exist or not, we finally need to do "a reality check ". Considering the reality of each idea, what needs to be emphasized is what we judge after confirming the mechanism about resources connected to the breakout of risks. To put it another way, utilizing the "AND/OR Logic", we had better practice the relationship analysis focusing on these resources. That is to say, it is clear that the resources based on the OR relationship make implementability of ideas higher. Table5 shows the portion of evaluation table based on "Resource Relationship Analysis" for ideas to realize "A management error is made" ,which is one of lower level harmful functions related to " No operation at the time of a disaster(one of selected harmful functions with star sign on diagram)" deeply connected to weak area.

As shown in Table5, we evaluated this idea (To neglect daily check) as "A" Level based on decision by a majority at the project team. Because in order to facilitate the project tasks, we think that our company might invest additional maintenance expense under severe budget condition, even low possibility of moral hazard. In addition this idea (See Table5), we were able to get several ideas evaluated as high event probability (A or B level) for the outbreak of risks. However, we don't show these ideas in the paper because of limited space.

TABLE 5 EVALUATION TABLE BASED ON "RESOURCE RELATIONSHIP ANALYSIS" FOR IDEAS

Selected harmful function : [No operation at the time of a disaster] ⇒Low level harmful function: [A management error is made]							
Idea(s)	The conditions necessary for realization	Dangerous resources (Relevant resources to realize dangerous things)	Possibility for an outbreak of dangerous things				Possibility of Ideas (Event probability) Consider OR&AND Logic
			High	Middle	low	No	
To neglect daily check	Shortage of maintenance expense	Directions on cost reduction	○				"A" level (adopted)
		Increase of maintenance cost	○				
		Reduction of fare revenue		○			
	Moral hazard	Inadequate education			○		
		Inadequate specialists			○		
		Inadequate internal control			○		
		Misapprehension			○		

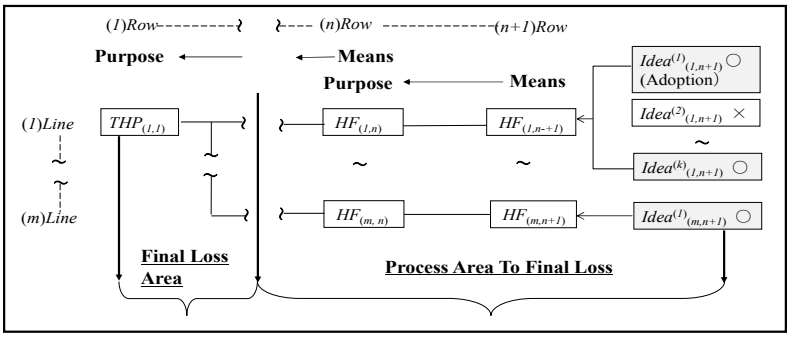
A level : (possibility of idea) high-middle B level: middle-low C level: low D level: absolutely low

STEP7: Organizing Scenarios for Realizing Risks (Countermeasure Stage)

Fitting together selected ideas (A or B level) logically, we have to integrate selected ideas as a series of "Risk Scenarios" (See Table6). To put it more concretely, understanding that each selected ideal correspond to each "Harmful Function" is a useful idea for realizing it, we have to integrate all selected ideas theoretically for making a series of "Risk Scenarios" with connecting to "Top Harmful Function (Final Loss). Fig.7 shows logical thinking for making a "Risk Scenario".

STEP8: Designing Measures to avoid Risks (Countermeasure Stage)

Through this step, considering how to avoid the implementation of" Risk Scenarios", we evaluate the effectiveness of proposed measures from the aspect of both technical and economic possibility and select highly-valued measures without obstacles to realize. After choosing them, keeping risk awareness, we try to practice the measures against risks. We drew up a lot of scenarios (A total of 33 scenarios) according to logical thinking for making a risk scenario (See Fig.7). After drawing scenarios, we divided all risk scenarios into two types. One is internal type and the other one is external. Typical risk scenarios regarding internal type are "Financial Risk" and "Increase Cost Risk" while risk scenarios regarding external type are "Armed Attacks and Terrorism Risk"," Flood Damage Risk By "Tsunami" after Earthquake", "Operation Risk by Soil Liquefaction after Earthquake", " Fire Disaster Risk by Arson Attack" and so on. Table 5 shows the risk scenario that is attracting the most attention.It's "Flood Damage Risk" and its proposed measures (portion). We used several "Directions (like checklist)" to think on the proposed measures effectively against risks (See Fig.8).



THP : Top Harmful Function(Final Loss) *HF* : Harmful Function)

Fig.7 Logical thinking process for "Risk Scenario"

TABLE6 RISK SCENARIO ABOUT FLOOD DAMAGE AND ITS PROPOSED MEASURES (PORTION)

Flood damage risk

Risk generating scenario		Existed dangerous resources	Proposed measures	Evaluation
Final losses	Envisioned process to reach the Loss			
Sea water & Sludge were sliding into the underground of the building by Tsunami and the earthquake-proof device did not work while the big earthquake.	The new building with "Buck Up System(BUS)" for traffic control system was built along the coast at the areas of Tokyo bay as one of risk measures to prevent D/B related traffic control system while incident(s) like earthquake	*Sea water in Tokyo bay (that might evolve into Tsunami after the big earthquake) *The stairway that leads to the underground (that might pour water on the BUS room.) *The soil of planned construction site for new building (that might be liquefiable)	New building for BUS should be built away from the seashore.	○
			Important equipment should be installed in upper floors.	○
			A breakwater (levee) should be built.	○
			Regular inspection and maintenance should be introduced	○

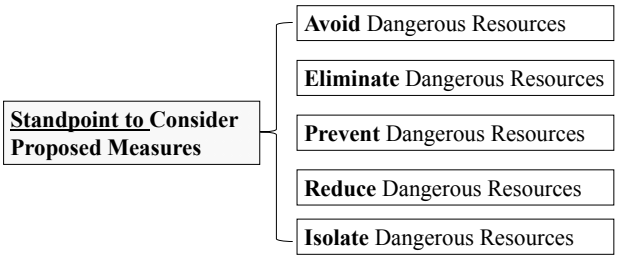


Fig.8. Direction to think proposed measured

VI. REVIEW OF THE RESULTS

We organized a total of 33 risk scenarios including flood damage risk scenario and proposed measures against each risk scenario through the procedure of CRMA. We submitted risk report about BUS of traffic control system (See Fig.9) to the company as the result of this project based on "Task Force Project (TFP)".

1. **A new BUS building** is proposed to be located at the place easy to be recognized; therefore, the building **cannot completely eliminate assumed main risk factors**
2. **A new BUS building** is proposed to have the structure **impossible** to be fully protected by the physically **destructive attacks from the outside.**
3. **The ground of the planned building is not taken a full measures against liquefaction**; therefore, there is a risk of damage to the building and the loss of power supply **after the disaster.**
4. **Many other existing buildings suitable for the installation are identified.** **The cost will be reduced** as compared to a new building.

Fig.9 Risk report about BUS of traffic control system

After releasing the risk report at the in-house TFP promotion committee, MEX, by considering the result of the risk report, selected another candidate site utilizing their existing facilities for the BUS, and started its second stage of TFP, or VE activity by examining the BUS alternatives with reasonable cost. As the result, it was found out that cost reduction of 25.6 %(reduction of about 2,420 million yen) was possible compared with the original budget for constructing a new BUS at new facilities. It was obvious that there was a significant difference between original plan and its alternatives by 2nd TFP. In fact, MEX had spent three years for making the original plan. On the contrary, in the TFP this time, it took two months until submission of the risk report about BUS, and another three months for making the proposal of BUS's alternatives at existing facilities, only five months in total, by making use of the unique RM method of CRMA. As the background, over the last more than ten years, MEX has experienced a number of successful projects based on TFP related to expressway's operation, by actively introducing MOT techniques including VE. That is to say, the problem-solving culture utilizing VE and TFP method was already taken root in MEX. It, therefore, was able to effectively utilize a unique RM method of CRMA based on "Function-oriented Thinking" of VE. Fig.10 shows the result about effectiveness of proposed method (CRMA).From this result, we realize that all respondents (six members) have positive feeling for proposed method. So we want to expect CRMA to be an effective method in the real field.

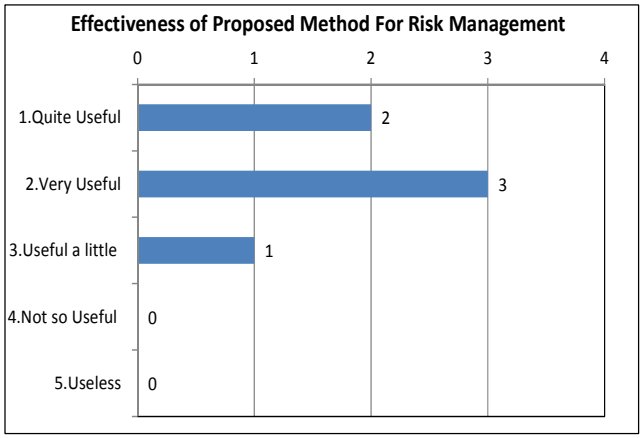


Fig.10. Effectiveness of proposed method (CRMA)

VII. CHALLENGES FOR FUTURE

There is one point to be noted here. As a result of following the steps of CRMA, creating the risk scenario about flood damage (in Table6) and proposing the measures, the original plan of building new facilities was substantially shifted to the plan of the BUS utilizing the existing facilities. In addition, the Great East Japan Earthquake on March 11, 2011, only a couple of months after our activity, had an enormous impact on us as almost the same things as described in this scenario (in Table6) actually happened in that disaster. The following *tsunami* caused the tremendous damage to Fukushima Daiichi Nuclear Power Plant. Even for that extreme situation which was by far beyond any expectations, by successfully formulating the creative risk scenario by means of CRMA with the help of imagination on risks, the risk aversion proposals could have been worked on beforehand. This project is believed to have proved that kind of possibility as well. Incidentally, there is an interesting finding from "Magnitude and Energy of Earthquakes (1)" and "Gutenberg-Richter Law (2)" which illustrates the relationship between the scale of magnitude and probability of earthquake occurrence (See Figure.11).

[Gutenberg-Richter law]
$log_n(M) = a - bM$ ····(2)
(M: Magnitude, $n(M)$:Number of Earthquake , a:intercept of vertical axis , b:slope of graph)

[Magnitude and earthquake energy]
$log_{10}E = 4.8 + 1.5M$ (M:Magnitude, E:Earthquake energy)
$E = 10^{(4.8+1.5M)} = A^{1.5M}$($A$:Invariable) ····(1)

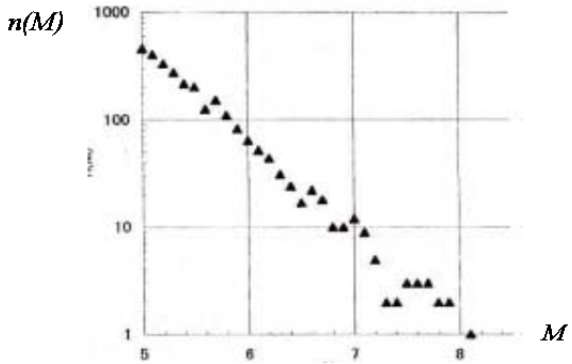


Fig.11. M- earthquake frequency distribution in vicinity of Japanese islands [13, 14]

Formula (1) shows that one increase in magnitude is an increase of about 31 times the amount of energy of the earthquake, if it increases by two, approximately 1,000 times the amount of energy is released. Formula (2) explains, however, that one increase in magnitude decreases the number of occurrence down to one tenth, it is down to one hundredth and one thousandth when the magnitude increases by two and three respectively. That means "Power-law" is applicable for the relationship between the scale of earthquake and the frequency of its occurrence. We can see that the frequency of magnitude nine earthquakes is extremely small, but at the same time, it is not small enough to ignore viewing from the comparison with the scale of energy.

According to "Gutenberg-Richter Law", the frequency of occurrence of a magnitude-nine earthquake in Japan will be once every three centuries. However, experts of earthquake prediction in Japan took it for granted that frequency of occurrence of it approximately would be once in 13,000 years as they adopted the historical frequency of earthquakes in local area (Japan) in the past fifty years. This "excess adaptation" was the interpretation adopted on the probability of the Great East Japan Earthquake before it happened [17]. In this sense, the method in this study, as it can improve sensitivity against risks and strengthen imagination and creative thinking against risks, will be an effective means for avoiding the application of "excess adaptation" against serious risks like big earthquakes.

There is another study saying that Japanese people tend to "underestimate themselves as individuals (meaning that they are humble about themselves)" but "overestimate their organizations (or they are relatively lenient when evaluating their organizations)"[18]. Risk management, in many cases, is implemented to organizations such as enterprises. In this sense also, this study result needs to be taken into account.

Even in a situation of a considerably large risk from the viewpoint of the people in charge of RM, if the risk items are difficult to quantify, "halo effect" can be anticipated by the severe evaluation made by those in and out of the organization (in this case, creation of the overall negative impression). Then, by being preoccupied to avert that, it is highly concerned to result in underestimation or making a lenient judgment even in the individual level. As a consequence, "the assumed risk" can be significantly lowered, and the enterprise may end up in suffering from tremendous damage. To prevent such tragedies from actually happening, the proposed method (CRMA) introduced in this paper is believed to be effective.

In fact, there have been a number of cases of damages far beyond any expectations related to IT-business risks(e.c. cheating in an university entrance examination using a cell phone in March of 2011) [14] and so on, and this method mentioned in this paper have already started to be applied [16]. The study of systematic verification of this method is expected to be continued including the effects for the ordinary operational risks which are difficult to quantify.

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