SECURITY, SAFETY AND HIGH RELIABILITY: ORGANIZATIONS IN COMPLEX SOCIO-TECHNICAL SYSTEMS

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ABSTRACT

The purpose of this thesis is to show the theoretical effectiveness of a *High Reliability Organization* (HRO) that attracts attention in organization studies.

In recent years, in the concepts of dynamic capability and operational capability in the Management of Technology (MOT) or Management Strategy, there has been one tacit understanding. In these discussions, it is to be assumed that the firms' infrastructure already exists. In other words, the firms, as the subject of this research, have been limited to the activity of the technical system infrastructure (e.g., manufacturing, energy, and distribution) which has already been constructed. However, a new doubt arises. How can the firms' capability within such an infrastructure be explained? That is, how is the infrastructure caused? And how does organizational change occur? We think that, from this aspect, our research is useful in organizational studies. As the recent organizational research illustrates, especially Actor-Network Theory (Callon and Law, 1997; Latour, 1999) and Practice Based Approach (Nicolini, et al., 2003), any organization is embedded in a socially constructed network, and the network cannot be separated from the organization (Latour, 1987; Ueno, 1999). It is important to research how the technical system is used by understanding organizational operations and organizational change.

Therefore, in this thesis, a HRO concept is presented as one means to understand an organization's technical system. Such an organization is highly safe and reliable, though this organization's environment is dangerous, meaning that a defect or mistake, and the ensuing trouble, is significant (Weick and Sutcliffe, 2001). That is, the situation is perceived to be sensitive, and the organization that installs the safety mechanism beforehand does so under circumstances in which the problem is very easily caused. The starting point of the HRO research is, "Why does the accident's seriousness and frequency, and the type of accident occur differently among organizations?" The research also considers the point, "Awareness of the issues that allow the discovery of various influential factor groups, based on prior experience research" (Nishimoto, 2004). This is different from the existing research of on organization that considers a technical system that has already been constructed. Furthermore, since the technical system and the organization are closely related, an organization should be concerned because of this relationship, and decide whether a problem occurs within an operation.

The thesis develops from this as follows. First of all, it explains from what aspect the error study of an existing organization has advanced research. Next, it takes a general view of HRO and studies it from a point differing from existing research. Finally, the Information

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and Communication Technology (ICT) industry, especially Internet Service Provider (xSP), is presented as a HRO case. Because ICT is a complex Socio-Technical system, there is a high possibility of connecting with the crisis with big and small mistakes, and the ensuring trouble. Therefore, the concept of HRO is easily suited. Moreover, these firms operate with the most advanced technology, as well as with various networks (e.g., government, firms, and consumers). In addition, the attitude of ICT operations is becoming more and more tough, bordering on the belief that, "Mistakes are not permitted." This is due to the enforcement of the Act for Protection of Computer Processed Personal Data Held by Administrative Organs, the introduction of Information Security Management System (ISMS), and the setting of Service Level Agreement (SLA). Therefore, showing the effectiveness of HRO in actual firms becomes possible by analyzing the ICT industry.

Keywords: High Reliability Organization (HRO); Complex Socio-Technical Systems; Information and Communication Technology (ICT); Three Error Researches; Social Constructed Network

INTRODUCTION

As recent organizational research, like the Actor-Network Theory (Callon and Law, 1997; Latour, 1999) and the Practice Based Approach (Nicolini, et al., 2003), illustrates any organization is embedded in a socially constructed network, and the network cannot be separated from the organization (Latour, 1987; Ueno, 1999). Since organizations are embedded in complex socio-technical systems, it is important to examine how the technical system is used by understanding organizational operations and organizational change (Whittington and Melin, 2003).

To this end, this thesis presents a concept of High Reliability Organization (HRO). Although an HRO is highly safe and reliable, its environment is dangerous; a defect or mistake, and the problems that ensue from it, is significant (Weick and Sutcliffe, 2001). That is, the situation is perceived to be sensitive, and the organization that installs safety mechanisms before they are needed does so under circumstances which can very easily create the problem. The starting point of HRO research is, "What is the accident's seriousness and its frequency, and what different types of accidents occur among different organizations?" The research also considers the concern of "Awareness of the issues that allow the discovery of various influential factor groups, based on prior experience research" (Nishimoto, 2004). Furthermore, since the technical system and the organization are closely related, an organization should be concerned because of this relationship, and it should decide whether a problem occurs within an operation. This thesis introduces and discusses the concept of HRO (High Reliability Organization) as the basis of its study of organizational safety and security, because the HRO perspective describes an organization as a construct embedded in socio-technical systems and as a complex socio-technical system in itself. This approach differs from the existing research on organizations, because the existing research considers a technical system that has already been constructed.

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THEORETICAL BACKGROUND: ORGANIZATION AS SOCIO-TECHNICAL SYSTEM

Socio-technical systems have not been recently discussed. However, this idea is very influential in present research. The socio-technical approach is a based in a series of studies executed at the Tavistock laboratory in the 1950's. The organization is assumed to be open and a socio-technical system. This research does not see the organization as closed system, and the organization is caught as a system that grows constantly by making deals with outside environments for resources.. This aspect continues to influence present research. In this chapter, the organization as socio-technical system is chiefly considered from three aspects.

Actor-Network Theory (ANT) and Technology

ANT locates all components with the same actor that participates in the network. Technology and knowledge are understood as something constructed on the network on the network formed with the interaction of each actor. Technology and knowledge are constructed with various elements. Therefore, it is thought to be difficult to discuss the organization without discussing either the interaction between actors or the meaning of these elements. Moreover, it is thought to be necessary that the process that generated the event be seen and described from a certain angle, and it doesn't make from the result of causing to the theory but complexly without differentiating. That is, the complex phenomenon doesn't observe simplification. Furthermore, the subject and the object, human and non-human are separated. This theory is based on a frame that understands has the network complexly. And because it understands the network complexly, the network necessarily becomes complex. That is, the theory's frame mandates complexness, because it is designed to understand the network complexly.

The Practice-Based Approach and Organization Learning

PBA assumes that the act of a person or an organization is buried by a social, cultural situation. The human and the organization construct a specific act to deal with a specific situation. So to speak, the act is caught by the form of the relation which contains the actor when the part when decided. Therefore, the act is thought to be dependent on the situation, and can be understood as restricted by the situation. Such research is not the search for another interpretation and the factor is not used to understand the consistency of the act only, but the meaning and the understanding of the act are assumed to be constructed by the local interaction or by the context that created it (Nishisaka, 1997). Therefore, the PBA researcher is presenting the idea of "situated social practice" (Lave, 1991). Situated social practice thinks that it adds the time concept to the interaction relation between the "activity" of the subject and the "situation." Because of this PBA researchers thought that catching by relating the subject's cognition change to the change in the relation between "activity" and "situation" became possible. That is, it is expected that cognition and communications will be built into the situation. Therefore, they are critical of the idea of concluding the discussion only outside/inside the subject.

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Recent work has made it possible to be interested in knowledge management. Since the 1980's, knowledge management has been chiefly discussed from three aspects; (1) Research that understands knowledge as an experience of cognition structure and action pattern; learning, therefore, is a process of changing cognition structure and action pattern (Kim, 1993; Fiol and Lyles, 1985), (2) Knowledge is the addition of high value to information, and it is an information set that includes technical competence (Davenport et al., 1998; Nonaka et al., 1996), and (3) Knowledge is an invisible resource, and one form of intellectual capital (Stewart, 1994; Bontis, 1997; Nahapiet and Ghoshal, 1998).

However, these three aspects follow a traditional western philosophy that stands in assumption that knowledge is being maintained by the individual. Therefore, in recent years, the knowledge management researcher changed from considering knowledge as a part of existence to knowledge as a process. For instance, Legitimate Peripheral Participation (LPP) research showed that the learner was engaged in actual work and knowledge was obtained (Lave and Wenger, 1991). They did not examine it in relation to what was happening in the individual's head; they studied what led the individual to introduce it into the participation frame.

This leads to the following clarification. An actor obtains knowledge under a specific situation, and constructs the problem. In a word, it is shown to decide the act according to the form of the place where actor is located (Callon and Law, 1997). Moreover, knowledge is to be constructed in a specific relation. Therefore, it can be understood that these are thought to be dependent on the situation, and it is difficult to discuss these phenomena without the aspect of "practice". Therefore, PBA becomes effective in the research.

The Organizational Factor in Error Research

The Normal Accident Theory is discussed as error research in the organization (Perrow, 1984). In the example of a nuclear plant, a petrochemical plant, and an airplane, Perrow shows the situation in which the specific factor (the breakdown of a specific person or a specific machine) in a highly developed organization that caused a particular accident cannot be identified. This research is called Normal Accident Theory. The accident just happens, and and the idea that it originates from a characteristic of the system matches the concept of Normal Accident Theory. Because measures for safety are given for each part of the organization, each mistake doesn't escalate into a major error. However, because in a highly developed organization, the subsystems are strongly interrelated, this could lead to a fatal problem.

In the background of this discussion lies a deterministic aspect of the technical system; it is based on the following ideas. It is thought that the technical determinism catches "technology" as the most important factor, and the structure is decided by the technical system's own inner structure (Kanbayashi, 2001). The technical system separates completely from a social and a systematic influence and exists independently. Therefore, the technical system maintains a logic in which the restriction might not be received by the social effect, and the technology is caught as a given that leaves no opening for dispute. Therefore, in a highly developed organization, an accident for an internal structure of the

system is created without fail. And, it was assumed that the "complex interactions" and "tight coupling" that existed in an inner structure was the cause of those accidents.

On the other hand, identifying the cause of the accident is dependent on research that sets its focus on the operator-human error analysis: who is related to the accident. Human error analysis has been researched from the perspective that human failure is the cause of some accidents. In the human error analysis, it is assumed that "everyone is the one who caused the error"; this perspective understands human existence as inevitably causing errors, because it catches as the cause the point where people's information processing ability, error generation level, accuracy of human memory, recognition bias, and tiredness cause error. The human error analysis is based on the idea that the mistake of the operating procedure and the recognition mistake of the situation caused the organization error. Such a research has been strongly influenced by Rasmussen (1987) and Reason (1990). For example, Rasmussen (1987) distinguished error as having three forms such as "lapse," "slip," and "mistake," and in addition advocated the model which classified human action at three levels: "skill," "rule," and "knowledge." Reason (1990) developed the Generic Error Modelling System (GEMS) so as to develop the model Rasmussen (1987) advocated; this system showed the strong influence of the human factor in error generation.

However, the necessity of doing an organizational analysis when error happens has led to error analysis of the firm. The human factor is able to explain the cause up to the level of the operator who chiefly caused the error and directly caused the accident, and analysis is not extensible even to the more inclusive human and systematic factors. Therefore, in present research, human error is not a cause, but is a result; the error occurs as a result of recognizing an organization factor as the cause of the error (e.g., Reason and 1990; Nishimoto, 2004).

As stated above, present research has developed the concept that organization factor is a cause of error. If an error began to occur as the operator of the organization repeats at a specific time, it is thought to be an approach of the idea that the change happens in an organizational structure and an employee's working conditions, and those systematic factors cause the individual to make an error that is the essence of the accident. And, the number of errors made by organizations will not change or it will only increase because the subject where the error is caused changes if the organization factor that is the source of the error is not recognized and repaired. However, in research, this very much results in the construction of a difficult situation. That is, it was comparatively a survey of narrow scope because it mainly located the error analysis in current technical and human factors and analyzed the situation of the workplace. And, if based on the idea that an organization is a big factor to make an error, the object of study grows significantly and the investigation becomes wide-ranging. If the essence of the error is not an organization factor, then searching for it there will not bring it to light.

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Figure1: Three Error Researches of Organization Study

Technical factor	→	Human factor	→	Organization factor
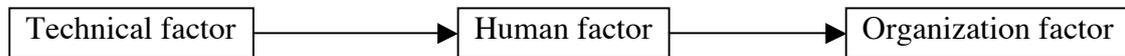
HOW TO CONSTRUCT SAFETY AND SECURITY?

Safety and Security as Emergent Properties in an Organization

In studies of organization theory and MOT, research on safety and security has been developed on the premise of determinism. Much of the existing research begins with a technological aspect; such studies are not designed to consider Safety and Security as an emergent property. This is amply evident in research on technology that has a close relation to safety and security.

For instance, it is noted that Emery (1966) locates the origin of a lot of problems in a social system within the technical system, and it was thought that this occurred because the discussion about business administration shaped the organization according to their technical needs. That is, the technology decides the role distribution of work and the relation between industries to optimize the performance of the entire organization, and through them it provides for a social system. Therefore, even if a social system has a problem, a social system cannot be easily changed because it has been decided by the technology (Herbst, 1974).

Woodward (1965) did empirical research on a British manufacturing company. As a result, the manufacturing know-how was classified into three groups: (1) unit and small batch production, (2) large batch and mass production, and (3) automated continuous production. On the other hand, constitution was classified into two types: (1) mechanistic structure and (2) organic structure. It was discussed that organization structure changed as the technology became more complicated, as it evolved from unit and small batch production to automated continuous production. As a result, the proposition of "technology determines organization structure" was derived.

Similarly, Perrow (1967) locates technology along two axes, "search" and "exception." Search indicates the exception frequency is caused by working, and how many of the problems are not preventable by the method of regulations. The technology becomes non-daily technology if the frequency is high. On the other hand, exception does show how, when an exceptional problem is caused, it can be able to be analyzed and solved. He was able to conclude that he showed that organization structure was suited to each technology, and that technology influenced each organization structure.

Thus, it can be said that in a current study, technology will be assumed to be an independent variable that provides for the community structure of an organization. On the basis of this idea, the technology is closely related to cultural, social, and political factors. But these are factors added by the technology, and the technology itself is assumed to have immanent and inherent "logic" and "impellent" (Winner, 1986; Murata, 1999).

However, when considering the findings of ANT, PBA, and Error Research described above, it can be understood that safety and security is constructed by the organization. Therefore, safety and security, seen as an actually purely technical result, become imbued with meaning by the organization and buried under the network. However, because this process is usually said to be evident, it is captured as just a technical result (Matsushima and Takahashi, 2003). Therefore, it can be said that safety and security have been understood as technical determinism. That is, because the current research on safety and security has only been analyzed from the one side, it can be said that it will come to depend on this aspect of determinism.

However, it is not provided as an absolute factor because safety and security is constructed by the interpretation and the support of the organization. Therefore, the possibility always exists that the required interpretation can change. That is, safety and security can be understood as an emergent property constructed by the organization, and safety and security differ from organization. In conclusion, safety and security does not exist 'out there,' independent of both the human mind and organization culture, ready to be measured. It is constructed in an organizational context.

Safety, Security and the High Reliability Organization

Thus, safety and security is understood as an emergent property, and one of the areas of research that attends to it is HRO research. In contrast to studies that think about safety and security deterministically, HRO research pays attention to why safety and security differ from organization to organization.

HRO indicates that the organization keeps the accident generation number at a substandard level, though it always acts under a severe condition (Weick and Sutcliffe, 2001). That is, the situation is perceived sensitively, and the same organization that installs the mechanism that prevents it beforehand is one in which the problem is caused very easily.

Weick has enumerated as concrete examples of HROs: a power station, the tactical air control system, a nuclear power aircraft carrier, a nuclear plant, an emergency health center, and a hostage liberation negotiation team. It is few that such an organization falls into the function stop though it is faced to the unexpected situation. However, when there is a greater probability of facing an unexpected situation, a very highly developed and complex technical system is used. On the other hand, in such circumstances, there is the high probability of falling short of the mark, compared with the organization previously described that manages a similar operation[0].

That is, a certain organization achieves extremely safe operation results and repeats the accident frequently, the same accident made by other organizations in almost the same

conditions (in terms of equipment, environment, and human skill and level). Why is the frequency and seriousness of the accident different according to the organization? The starting point of the HRO research is the awareness of the issues that lead to the discovery of various factor groups that influences their investigation of an actual organization. HROs' basic concept assumes that its problems would be safely managed by other organizations though in those systems thought that the accident was inevitable.

Roberts (1990), an HRO researcher who objected to the assumption that complex interaction and tight coupling cause the error in the organization, argued instead for the following 4 points that the Normal Accident Theory had presented: (1) redundancy, (2) accountability, (3) responsibility, and (4) a culture that can be trusted.

Weick and Sutcliffe (2001) discussed whether, in continuing the organization, it is important to manage the unexpected situation well, and that depends on whether people can achieve the following five factors in the process of operating the organization: (1) preoccupation with failures rather than successes, (2) reluctance to simplify interpretations, (3) sensitivity to operations, (4) commitment to resilience, and (5) deference to expertise. These five factors organize an employee's mind. And, it is assumed that when an employee's mind is highly organized a high performance in an unexpected situation becomes possible. In the following, it is assumed that we easily explain those factors.

(1) Preoccupation with failures rather than successes
When failure occurs, something has been overlooked, or the system is not in a healthy condition. One should understand past failures well, so that precautions can be strongly considered, and the system changed so that it doesn't fail.

(2) Reluctance to simplify interpretations
To precisely adjust the organization activity, it is necessary to concentrate on a certain problem and its solution. It is necessary to concentrate on a certain problem and the solution to adjust the organization activity well. Simplifying is a convenient way of doing that. However, that leads to ruin other questions at the same time. Therefore, limit the simplified one, and pay attention to more important things.

(3) Sensitivity to operations
In a current research, the strategic decision and the operation of the strategy are divided and have been discussed (Whittington and Melin, 2003). However, in the discussion concerning PBA, the organization is assuming that the activity has not been approved by the hierarchy, but at the practice level (Nicolini, Gherardi and Yanow, 2003).

(4)Commitment to resilience
The organization's existence depends on trying to prevent and to forecast the unexpected situation, not on the fault being avoided. Therefore, when the unexpected situation happens, it becomes important to know how the system responds to it. This ability is caused by "network that consists of people who have expertise," "various counter measures," and "using the skills needed to deal with it unexpectedly."

(5)Deference to expertise

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A rigid organization structure has the following weakness. The error of top management is passed down to middle and lower management, and as a result, the error may become magnification and indistinct. Therefore, it creates a more serious problem. To deal with this, the person who maintains the exclusive knowledge about the problem should do the decision-making.

In HRO, it is assumed that a member will be mindful once these factors have been constructed. In this situation, the member is seen to complete the following three steps: (1) Try to do a detailed differentiation of the category of the event continuously and positively, (2) Try to apply a new category to the event that occurs regularly, and try to discover a significant pattern to maintain, and (3) Try to devise the reading action method to give a slight difference of meaning to the situation. On the other hand, in a mindless organization, a past category is applied to the present event, a preset action is done, and this leads a new situation to be misidentified with a situation that has already existed since before the organization stopped changing (Langer, 1989). That is, in an HRO, mindfulness and various measures synchronize closely, and this is vital to a member's high performance.

Then, how do you think that safety and security is constructed in an HRO? In an HRO, safety and security influences a member's mind by means of the five elements of the operation of the organization. And, it is thought that safety and security result (see Figure 2). That is, safety and security are emergent properties caused since those are neither a technical result nor a human result but a close interaction of the two.

Figure2: How to construct safety and security in HRO
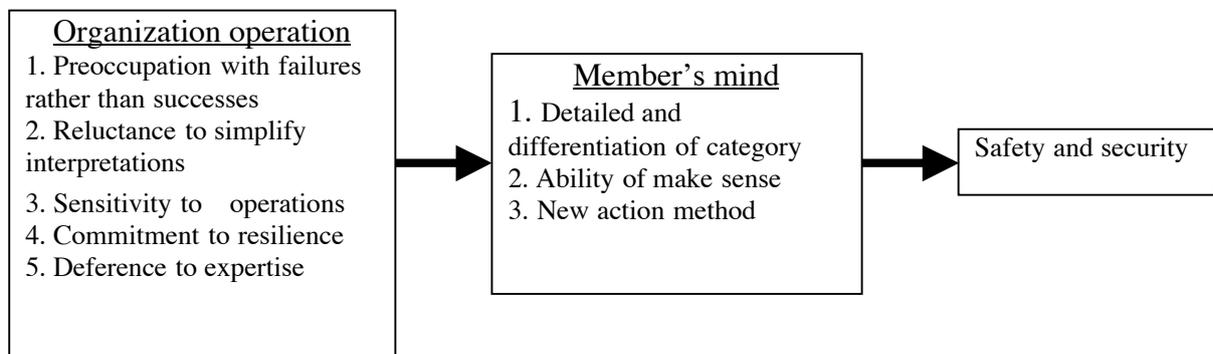
CASE STUDY: SAFETY, SECURITY AND HIGH RELIABILITY IN THE ICT INDUSTRY

This section considers safety and security in the HRO previously presented in ICT industry. The ICT industry undertakes business with an advanced technical system, and it is greatly influenced by the outside environment. In such a situation, the ICT industry of Japan does a very advanced operation. For instance, Takagi (2006) researches MTTR (Mean Time To Failure) that is the index of the operation utilization rates as a result variable. In this study, ICT is shown to assume that the operation will have a high continuance. It is thinking like

this that makes the ICT industry an organization that maintains advanced safety and security. Therefore, it is assumed that "organization operation" and the "member' s mind" that invents this safety and security are seen as follows, and in accordance with the result of the interview and the questionnaire survey in Nakanishi (2006) and Takagi (2006), given to the ICT industry.

Organization operation

(1) Preoccupation with failures rather than successes
In the firm in the study, information about past problems had been collected in a data base. The operator responding to the trouble registers it in the data base. In addition, a conference is held where the group member reports on the situation. A team for problem–solving, which includes the customer, is organized, and the firms exchange opinions information. In a word, the importance of a frank opinion exchange and the intelligence sharing is understood. Moreover, an experiment reproducing the problem that occurred in the operation section is executed, and the result reported to a related section. On the other hand, to encounter the trouble first is to "get the breakdown" and a team praised the man who reported it.

(2) Reluctance to simplify interpretations
A certain firm concentrates on not the assumption that the breakdown correspondence in the place only has to settle down, but on tracing the customer's demand related to the breakdown over the long term, and on confirming the situation. In addition, opinions from different viewpoints have been exchanged at the conference at which the members of the other business departments, such as R&D and sales also participate. That is, various methods are used, and have not been simplified. Furthermore, the person who is acquiring the action ability is experiencing more than the person who does the action method of regulations and is valued for that. For instance, in some firms, the ability to "Shape that not is before" can be recognized and is valued and arranged in the form of the person in charge of IDS (invasion detection device). Moreover, as receptivity to the accident is maintained, the firm in which the manager is appealing to the operator that he/she works frequently visits other departments like R&D and sales, and shares information.

(3) Sensitivity to operations
For instance, the network operation center was consolidated in one place, and there was unified management of the various operations of the communication service. Moreover, one firm used two methods of communication: (1) electronic media like a trouble ticket system, mailing list, and database, (2) face-to-face communication like talking over the work, and meeting. The problem was clarified by posting it on a whiteboard, and there was a case where once everyone noted the situation, it was removed. These are bases that secure richness of information, and urge awareness in the operation.

(4) Commitment to resilience
When the trouble happens at a lot of firms, the Escalation rule and the Escalation passing are set to correspond to it. In some enterprises, especially telecommunications providers, there is an approach to telecommunications that includes a related section in another city for when the trouble occurs, and prompt decision-making. In the problem correspondence, one

firm that pointed out the importance not of the self-conclusion in the department but to the customer, sales department, and the customer service department and approaches for the problem-solving. Moreover, when a similar trouble occurs, an emergency measure for relapse prevention is made during the meeting, and the expansion of the unexpected situation is controlled.

(5) Deference to expertise
The enterprise that exchanges human resources between the different teams that support a business in the operation section exists to adjust to various troubles. Moreover, the case also led to constructing the Escalation passing to make it correspond to a special skill. These show that an approach exists for straightening the system to correspond flexibly. For instance, so as not to fall into a panic during an actual operation, a simulation is done using actual operation machine parts, and the operator's expertise is improved. Moreover, one firm executes a skill check for the person in charge approximately twice a year. In addition, another firm unified the schedule and positively executed the operation training.

Member's mind

Takagi (2006) greatly altered Weick and Sutcliffe's (2001) questions to measure the minds of the members of the ICT industry, and constructed the questions that focused on the operator of ICT. The questionnaire survey was executed for the person in charge and the manager of the operation. When the data was tested, significance existed in three elements: (1) detailing and differentiation of categories, (2) ability to make sense, and (3) new action method.

The first element is that which does not stick to an existing category, but pursues the root of the problem and in which energies are devoted to solving it. The specific question is "it thoroughly analyzes when the problem occurs and tries to try to understand essence," and "the event that can occur exceptionally is listed beforehand, and it is shared with the correspondence method in the department" and so on. In second element, both the questions of "observance of the procedure when the business was accomplished" and "a severe norm with the person in charge is imposed" were the results of the minus. Because this question item expresses pressure in the operation, the minus shows "freedom from pressure." In the new action method, the last element, the specific questions are: "it is necessary to locate the cost for the failure prevention" and "the challenge to the duty that exceeds my ability is encouraged." This confirms whether to recognize the necessity of human and financial "investment in the defence" so that the unexpected situation can be forecasted and controlled. Because of this, significance exists in all three elements. This can be said that member's mindfulness is high in the ICT industry.

CONCLUSION AND FUTURE RESEARCH

In this thesis, safety and security were discussed as emergent property of the organization as socio-technical system. The concept named HRO was presented as a construction process of safety and security on that topic. In addition, how safety and security were constructed was discussed by using the case of an actual ICT firm. This was able to present a new aspect that

is different from the discussion in which safety and security were constructed with technology.

What follows are possible future subjects. First of all, in terms of theoretical subjects, expanding HRO research as a general enterprise and examining an analysis object that is a special case like an aircraft carrier or a tactical air control system. Therefore, not only various concepts of a current HRO research but also the addition and the correction of a new concept are needed. These developments are enumerated as a theoretical problem. Next, in practical subjects, there are a lot of notional concepts of HROs. Therefore, it is necessary to accumulate empirical data to make it make to exquisite, and to develop accurate standards that measure the organization.

Moreover, not only the error research but also there is a need to consider the relation to organization performance. This thesis mainly discussed the relation between safety and security and the organization. The effectiveness of this thesis exists if it thinks about the situation in which the research of HRO has not progressed too much in Japan. However, in future research it will be necessary to explain how this type of organization is related to organization performance

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