R&D SYMPOSIUM ROUNDTABLE

COOPERATION WITH THE UNIVERSITY OF TOKYO "SAFETY ENGINEERING ENDOWED CHAIR"

Tomonari Yashiro

Professor, Institute of Industrial Science, the University of Tokyo

Specialty: Architectural production, management of technical innovation, technical ethics
1985 DE, Graduated from doctoral course at School of Engineering, the University of Tokyo
Started work as a researcher at the Building Research Institute of the Ministry of Construction
1990 Chief researcher at the Building Research Institute of the Ministry of Construction
1991 Associate professor, Department of Architecture, Musashi Institute of Technology
1998 Associate professor, Department of Civil Engineering, School of Engineering, the University of Tokyo
1999 Associate professor, Institute of Industrial Science, the University of Tokyo
2001 Professor, Institute of Industrial Science, the University of Tokyo
2004 Faculty member in JR East Safety Engineering Endowed Chair under the Division of Project Coordination (also holding other posts)
2005 Executive Advisor to the President, the University of Tokyo

Masamichi Kato

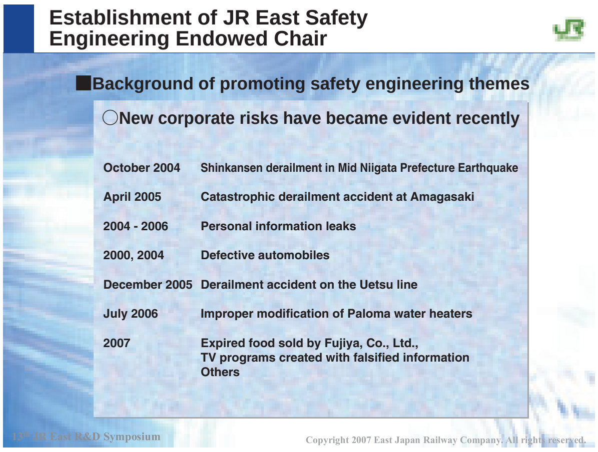
Director, Safety Research Laboratory, R&D Center of JR East Group

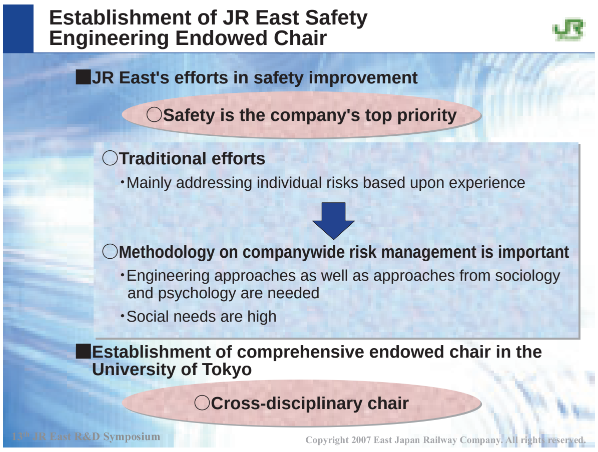
1 Purpose of Endowed Chair in University: by Masamichi Kato

Here I will explain the background behind the establishment of the Safety Engineering Endowed Chair.

This endowed chair was started in October 2005. The Mid Niigata Prefecture Earthquake had struck in October of the previous year, and in that we faced the derailment of a Shinkansen train running at 200 km/h. Although such an accident in a major earthquake was not beyond our comprehension, we had not yet taken actual countermeasures against that. This was also a time when we were faced with a catastrophic derailment accident at Amagasaki in April 2005 and a derailment accident on the Uetsu line in December of the same year. Also, many other accidents and events had occurred in various fields other than railway business. That is to say, there was a situation that a variety of new corporate risks were becoming evident.

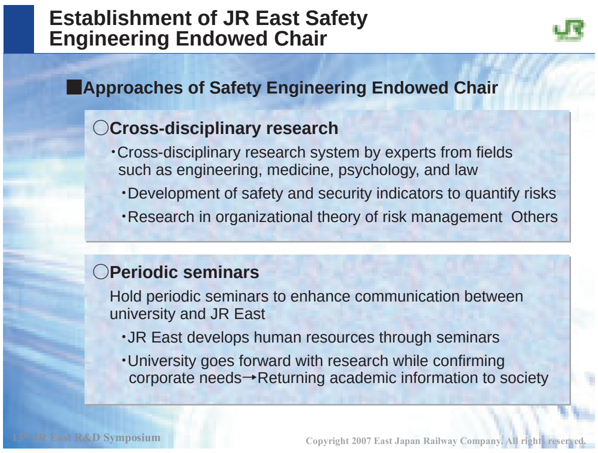
We have been tackling safety as a top priority issue since the company's foundation, but traditionally efforts centered on addressing individual risks based on past experiences. The aforementioned situations however boosted awareness throughout the company that it is important to develop a methodology on total risk management in addition to traditional efforts. We thought that such a methodological effort requires more than just an engineering approach; approaches from sociology, psychology and many other fields would also be necessary. We further realized that social needs in regard to those





were high. Therefore, we decided to address this challenge by endowing a university chair. Upon consulting with the University of Tokyo with its vast human resources in a wide range of fields, they proposed the establishment of a comprehensive endowed chair, a new course system for cross-disciplinary study.

This endowed chair was given the name "JR East Safety Engineering Endowed Chair" and become the first case in the comprehensive endowed chair system by the University of Tokyo. Now I will point out two features of this chair. One is its cross-disciplinary research system, in which experts from many fields such as engineering, medicine, and psychology are carrying out quantitative risk assessment and research on risk management. And the other is periodic seminars that our research staff and experts from the University of Tokyo in this chair hold together for mutual communication. From a standpoint of developing human resources, this is a very stimulating venue that our young researchers can take part in. Also for the University of Tokyo, I believe that this helps promote research while discovering corporate needs and refine the research from the perspective of university's relationship to the society.



As explained, we have started an unprecedented system of a comprehensive endowed chair. We have just passed the halfway mark in the schedule, and we will finish in the next spring. But JR East will continue to engage in the research as an active corporate partner to produce meaningful results.

2 Safety Engineering Endowed Chair: by Prof. Yashiro

2.1 Outline of the Endowed Chair

In the circumstances just introduced, we have come to conduct a safety engineering endowed chair. Here I will explain the current progress and prospects.

As Mr. Kato mentioned, this is a new style of endowed chair for us. Mr. Fujita of our university and Mr. Kobuki of Toyota Motor Corporation pointed out in the keynote speeches today that industry's relationship with universities is evolving from personal relationships with individual professors or experts to organized relationships with universities as a whole. This endowed chair is based on such a big trend. JR East extended an invitation to our president's office to study and research safety and security together with the University of Tokyo. As shown below, we have comprehensive chairs that call on academics from various fields under the administration of the university's president. That organization was established in July 2005 and it will mark three years since the start of the activity in October next year.

The purpose of this endowed chair is, as already explained, to develop solutions to various explicit risks relating to safety and security by joining the forces and abilities of the company and university.

Based on that offer, we established a kind of mixed team. Dare I say it, although a university might look united, it is actually like a federation comprised of faculties as departments and research institutes as independent entities. We sometimes have no idea what our colleagues in other departments are doing. With this opportunity, we have formed a system to call on persons concerned in different departments under the keywords of "safety and security" and to study together. Prof. Horii and Nakao and myself are engineers. Prof. Horii specializes in civil engineering, Prof. Nakao in mechanical engineering, and myself in architectonics. Prof. Ikeda specializes in social psychology and Prof. Shiroyama in law; while Prof. Karima is a medical expert licensed in clinical surgeon and has worked in the emergency care field.

Purpose of Endowed Chair

- To develop research methodologies to reduce total risks in light of the current status where there are evident corporate risks such as the Mid Niigata Prefecture Earthquake and the derailment accident in Amagasaki.
- To contribute to creation of total social security by proceeding with research with a broad perspective that is difficult to carry out by a single company. This is done based upon comprehensive and cross-disciplinary approaches utilizing the university feature of having a variety of researchers and experts.

Members

Hideyuki Horii, Prof., Graduate School of Engineering (also holding other posts)
Tomonari Yashiro, Prof., Institute of Industrial Science (also holding other posts)
Masayuki Nakao, Prof., Graduate School of Engineering
Kenichi Ikeda, Prof., Graduate School of Humanities and Sociology
Hideaki Shiroyama, Prof., Graduate school of Law and Politics
Risuke Karima, Associate Prof., Environmental Science Center

There are many instances of endowed chairs that are sponsored just for attraction and filled almost only by university staff. But this endowed chair has, as Mr. Kato mentioned, a strong feature whereby JR East staff and our university work interactively. Specifically, those experts from different fields join together and explain the progress of their research on safety and security at periodic seminars. The staff from many departments at JR East, mainly from the Safety Research Laboratory, participates there and presents questions and suggestions regarding our presentations. They also introduce research at JR East on similar themes at the seminars. Such interactive operation is the strongest characteristic of the endowed chair.

Characteristics of Activities
Interactive cooperation and integration of different fields

- Integration of different fields taking full use of university features
- Daily research as well as approx. six seminars for presentation of research and for discussion →Interactive cooperation

  Active discussion and information exchange by members including staff from Safety Research Laboratory of JR East and other universities

The research themes decided at the start were quantification of corporate risks and research in organizational theory of risk management to enable accident prevention. Six persons in charge to be introduced here are carrying out their individual research.

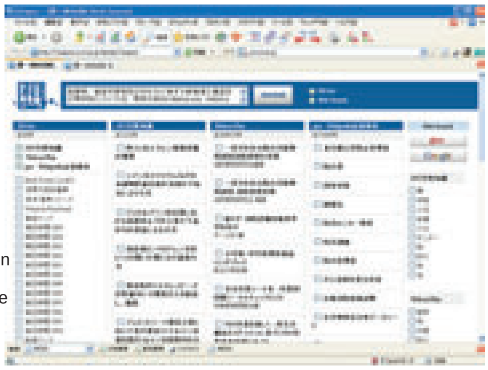
Study Themes Decided at Start

- **Developing safety and security indicators to quantify corporate risks**
  Form an effective sampling method of corporate risks for corporate risk management and quantitative assessment method of sample corporate risks. Form safety and security indicators for effective actions to reduce corporate risks including risk communication.
- **Researching organizational theory of risk management to enable accident prevention**
  Have a shared in-house attitude, vision, policies and rules about safety and clarify requirements to encourage independent safety actions of employees. Define requirements of organizational theory to appropriately pick up worksite risk information and address it at proper sections. Make recommendations on how and what risk management to is needed for accident prevention.

2.2 Research Themes

Prof. Nakao is preparing a database on failures in this research and creating structured knowledge about failures. When a database on failures in an organization is completed, people of the organization often think that they can immediately learn lessons from that. But in this research, Prof. Nakao is verifying whether such a database can really be of use to everyone while conducting overall research.

Development of Implementation Design Method to Use Failure Information in Organization as a Whole
Masayuki Nakao



Search display of failure information database by imagine

When he offered a database actually prepared to people—mainly members of the Japan Society of Mechanical Engineers and students—who have different levels of literacy and ability and checked whether they can draw the required information from the database as intended, he found that they cannot always obtain such information. Thus, preparing such a database is not enough. He is now conducting further research into how such a database can be used as knowledge for people and how to make it contribute to risk management.

Exercise Results

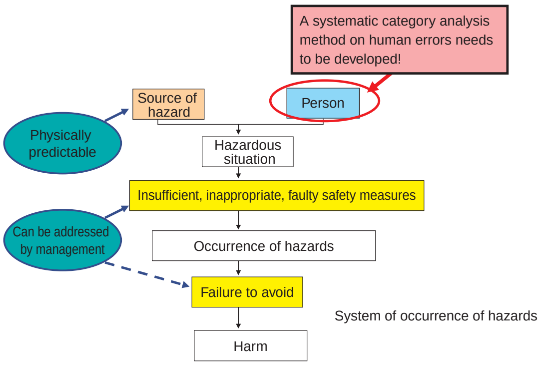
Masayuki Nakao, the University of Tokyo

Proportion of students who could output similar data	Proportion of examples where a student could output similar data when inputting more than 1,000 characters (including instances where a student could make multiple outputs)	Proportion of examples where a student could output similar data when inputting less than 1,000 characters (including instances where a student could make multiple outputs)	
Members of Society of Mechanical Engineers (first time) 2006-11-17	12/25 (48%)	9/10 (90%)	8/20 (40%)
Members of Society of Mechanical Engineers (second time) 2006-12-22	13/19 (68%)	15/21 (71%)	4/7 (57%)
Members of Society of Mechanical Engineers (third time) 2007-1-19	10/17 (59%)	10/13 (77%)	12/24 (50%)
Lab students (trial) 2006-10-11	7/9 (77%)	8/11 (72%)	—

Not everyone can search out similar data.

Associate Prof. Karima's keyword in this endowed chair is "human factor". He is focusing on risk assessment regarding human factors. The figure below shows an illustrated analysis how human errors relate to actual accidents.

How conduct risk assessment for human factors
Risuke Karima, Environmental Science Center



The following figure shows instances of accidents that actually occurred in our university, including minor ones. Prof. Karima is now carrying out structural analysis of the relation between human factors and real safety while analyzing what kind of human errors caused the accidents.

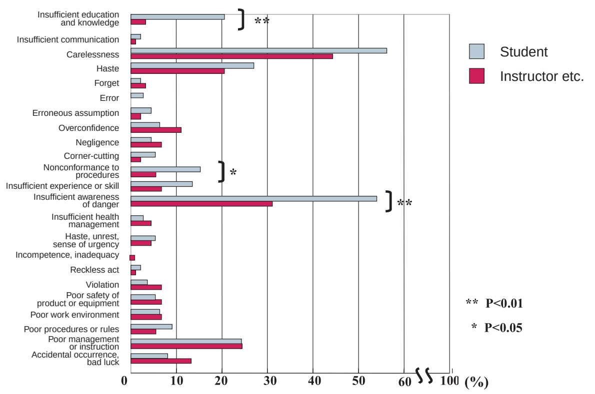


Fig.1: Ratios of Accident Factors in Accidents and Incidents by Students and Instructors

Prof. Horii is working on two themes. One is to develop an indicator of safety and security that is closely related to the purpose of this endowed chair. He is conducting assessments of individual risks by means such as a questionnaire survey.

Development of Safety and Security Indicators to Quantify Corporate Risks (Hideyuki Horii, Mizuki Yamazaki)

- **Sampling of indicators based on social psychology (responsibility attribution theory)**
- **Sampling of indicators related to after-the-fact actions**
- **Assessment of individual risks by questionnaire**

The other theme Prof. Horii is working on is to clarify how safety-related social trust in companies is built. He is currently analyzing and clarifying requirements for such trust surveys.

Building of Social Trust in Companies Regarding Safety (Hideyuki Horii, Mizuki Yamazaki, Aya Takagi)

Purpose: To clarify requirements that improve social trust in organizations taking safety measures

Overview of research:

Survey 1: Comparison of trust in organizations relating to traffic safety and typification of such organizations (online survey, 1,070 valid responses)

Survey 2: Defining factors of social trust in companies (questionnaire survey, 1,081 valid responses)

Survey 3: Effect of information on corporate websites on trust building (on-site survey, 250 persons)

The following figure illustrates an analysis how trust in transportation safety is brought about. We hope that these studies can offer systematic knowledge to build trust in transportation.

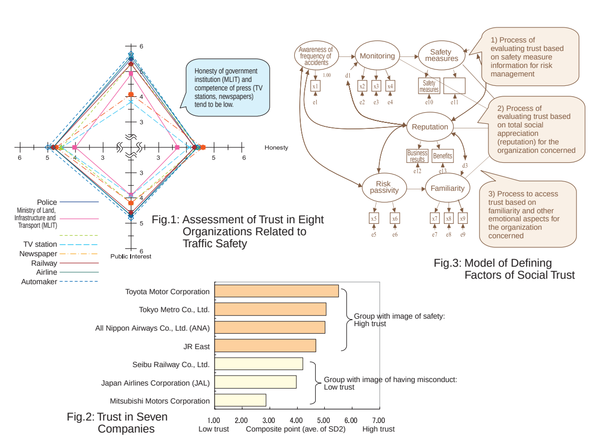


Fig.1: Assessment of Trust in Eight Organizations Related to Traffic Safety

Fig.3: Model of Defining Factors of Social Trust

Fig.2: Trust in Seven Companies

Prof. Shiroyama is a legal expert who is researching the relationship between technology and law. Although laws in particular function to make deterministic provision, scientifically there remains uncertainty. And we think that legal structure must not prevent innovation. In this endowed chair, Prof. Shiroyama is researching what kind of legal structure should be built on the condition scientific uncertainty and innovation are not hindered, and if such a legal structure can work as an essential risk control system.

He has an understanding that risks can be managed and controlled only when there are organic self-control systems for companies rather than simply legal regulations by governments, as shown in the second paragraph of the following figure. Based on that, he is researching how such flexible rules can be made out.

Cross-Disciplinary Study on Rules and Organization System to Ensure Compliance, Hideaki Shiroyama, Graduate school of law and politics

Subjects

- **Study of a law system to address scientific uncertainty and uncertainty of social benefit in risk assessment and control**
- **Study of a flexible integration form of voluntary control systems of companies and governmental legal systems (responsibility to be clearly separated, not too ambiguous, and transparency to be secured)**
- **Communication and peer review as a focus of a voluntary control system by establishing a quality assurance system**
- **Cross-disciplinary comparative analysis**

Based on actual instances in area such as nuclear power or transport safety, he is analyzing the aforementioned issues in depth.

More Flexible Rules to Address Scientific Uncertainty

(1) Using rules allowing deviation
Ex. nuclear power: When government institutions uses private-sector rules, they should take private-sector rules that define specifications as institutions standards etc. on Administrative Procedures Act, based on the performance standards by agencies concerned. Judgment standards are just reference standards for judgment and do not always require compliance. That is different from use of private-sector rules in notices that do not allow deviation.

(2) Attempt to incorporate a continuous communication process rather than set explicit standards / Quality assurance system / Focus of comparative analysis
Ex. Transport safety regulations: Operators are obligated to prepare and report safety management standards.

(3) Note
Incentives and resources for continuous improvement of private-sector rules
Possibility that checking by a quality assurance system becomes formalistic (with or without documents etc.)

His study scope is technically highly cross-sectional, covering nuclear power, medical care, foods, and railways. He is trying to create academic achievements to those issues in these fields.

Prof. Ikeda specializes in social psychology. He is researching the system how people's trust in companies is built.

Specific Details

- **Examples of and hearings on actual application of quality assurance system**
  - Nuclear power (security regulation)
  - Medical care (medical functionality assessment mechanism, mutual checking system)
  - Food (overall hygiene management production process)
  - Railway (transportation safety management assessment)
- **Scope of analysis**
  - System at the worksite, Ensuring competence of personnel who perform management review, Communication between safety related sections and management, Peer review
- **Focus of analysis**
  - How to design a legal system that does not become formalistic
  - Possibility of mutual reviewing (trials in nuclear power industry by Institute of Nuclear Power Operations (INPO), and in medical care)
  - Consideration of industry structure (large difference in size in transportation and food businesses, difference of relationship between manufacturers and operators and difference of design ability balance in electric power and railway businesses)

Understanding and Empirical Examination of Trust in Companies Kenichi Ikeda, Graduate school of Humanities and Sociology, The University of Tokyo

- **Applying the development of socio-psychological research on trust to research on trust in the private sector (companies)**
  - Studying what factors comprise trust in companies
  - Examining key factors of building mutual trust between companies and citizens
- **Research results so far**
  - The effect of corporate ethics as trust and sense of security in physical/mental aspects is evident. The effect is stronger than factors for risk awareness.
- **Future subjects**
  - Studying interpersonal trust and trust in private sector by analyzing total structure of trust in corporate/public systems
  - Studying relationship between professional ethics and civil ethics of workers and corporate ethics by using the concept of technical ethics by Mr. Yashiro et al. (2005)
  - Making structural arrangement and positioning of effect of variables relating to risks

He has carried out surveys how such trust is actually formed, and the following figure shows an instance of the analysis of his survey. He is trying to reveal the way such trust in a company is formed by clarifying elements that compose such trust and the relationship between trust and those elements.

Explanation of Trust

- Stratified sampling by sex and age from Dcamp panel of Dentsu Research Inc. (data for a project by Research Institute of Science and Technology for Society)
- Surveyed men and women age of 20 - 59 living in Tokyo, Saitama, and Kanagawa
- Survey period: Feb. 10 (Fri.) - 20 (Mon.), 2006
- Response rate: 86.7% with 1,084 responses to 1,250 questionnaire cards sent
- Analysis: Robust regression analysis of scaled variables: Used responses about JR East, Tokyo Metro, and Seibu Railway to the same question as repeated measurement data.

- Total indicator of trust is dependent variable.

→Independent variables show strong effects of ethics (trust). Studied if effects of trust (ethics) remain even when inputting "safety" at the same time.

→Effects of trust (corporate ethics) are evident even when effects of sense of security (monitoring and safety) are deducted.

- Effects of safety factors are evident too. Soft monitoring is effective in particular, but safety measures and reputation are effective, too.
- Social participation is not a factor in private sector.

→Differentiating trust and security is especially useful, rather than to consider from the logic of social infrastructure.

- Effect of risk-related variables on trust is not evident.

Dependent variable, Trust, Sense of responsibility

		model 6	
			t value
Social participation variable	Formal participation as organization	−0.02	−0.92
	Informal participation as group	0.03 +	1.79
Interpersonal network variable	With or without acquaintance in railway company	−0.05	−0.63
	With or without acquaintance in railway company	0.13	0.98
Corporate ethics variable	Corporate ethics	0.28 **	17.98
Security variable	Awareness of safety measures (physical)	0.06 **	3.39
	Awareness of monitoring functions (mental)	0.14 **	7.06
	Accident experience	−0.04	−0.65
	Reputation	0.03 **	3.34
Risk variable	Even if safety measures are omitted, effects do not appear at once.	0.02	0.76
	Accidents or troubles affecting train operation (ex. signal trouble) often occur.	−0.11 **	−3.42
	Even if there is a problem in safety measures, ordinary people are only aware of that when an accident occurs.	0.04	1.5
	Accidents or troubles affecting train operation (ex. signal trouble) affect many people.	0.01	0.3
	The kind of damage in case of an accident can be expected.	−0.03	−0.94
Relationship to basic railway safety and security	Diversity of information source related to traffic safety	−0.02	−1.21
	Interest in traffic safety	0.02	0.45
	Sense of effect	0.02	1.11
	Familiarity	0.05 **	4.95
	Frequency of use of railway	0.08 *	2.25
	Unavoidability of use of railway	0.00	0.23
Demographic variable	Sex (female)	−0.07	−1.12
	Age	0.00	0.59
	Marriage status (married)	−0.01	−0.09
	Engineering-related job	−0.08	−0.68
	Management post	−0.14	−1.31
	Educational status	0.01	0.39
Railway company dummy variable	Tokyo Metro	0.15 *	2.39
	JR East	−0.13	−1.55
	Section	−0.56	−1.33
	Observations	2890	
	Cluster	1011	
	R-squared	0.62	

* significant at 5% level; ** significant at 1% level
Bold type is variables measured per railway company.
Base category of railway company dummy variable is "Seibu Railway."

2.3 Research Theme of Prof. Yashiro

Now, I will introduce a little about my own study. My theme in this endowed chair is ethical risks. When technical misconduct occurs, people often emphasize the need to bring manuals and to promote legal compliance. But, in order to avoid ethical risks, it is necessary to create a feasible and workable organization system and make it work. This is the starting point of my study.

In analyzing actual misconduct and accidents, what I am paying attention to is that there are many cases where engineers actually in charge face difficulties between many different codes of practice. Error in finding the way results in social criticism personally to himself, while mission statements of the company advocate admirable policies. To put it the other way around, engineers are daily facing such conflicting values. The starting point of my research is that it is rather more important to find how an organization should address such a dilemma as organizational risk management.

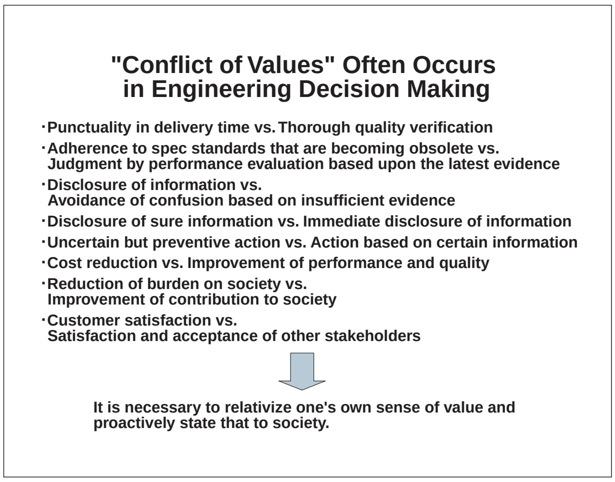
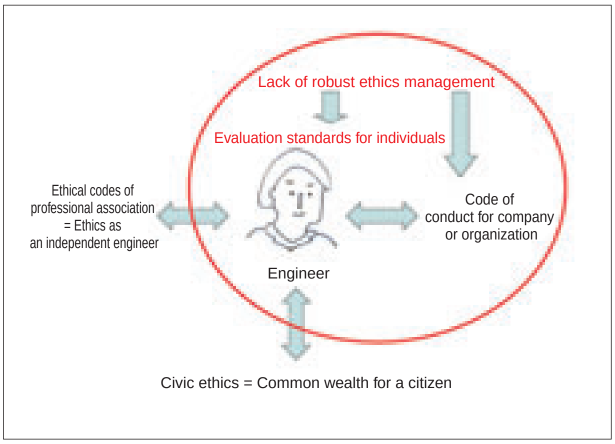
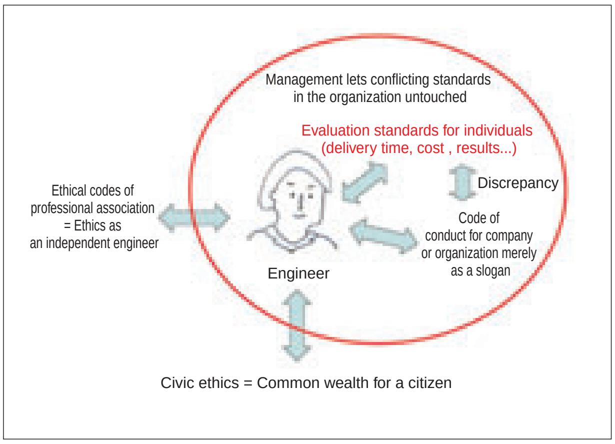


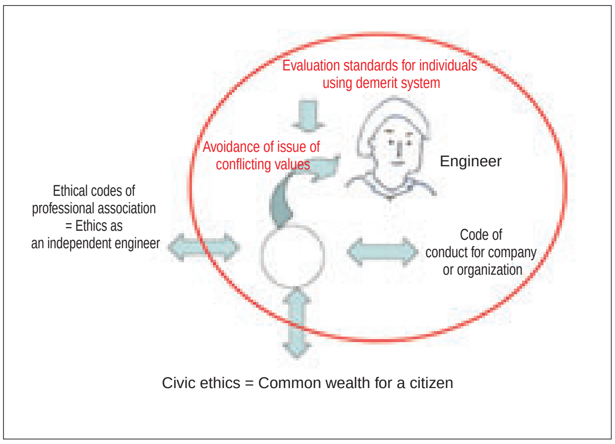
Illustration of actual conflicting regulations indicates that there seem to be three kinds of codes of practice that engineers have to work with today. One is the codes of an organization or a company an engineer belongs to. The second is codes of practice that an engineer has as a citizen or individual away from the company. And the third is codes specified by an engineers' professional body such as a society of civil engineers or a society of mechanical engineers. In the past, there was an era when happiness as a company employee, a family member, and an engineer all agreed with each other; but the analysis of today's misconduct and accidents shows that there are many cases that these three vectors are not always in accordance. I am analyzing why such disagreement occurs and what kind of conflict in values occurs, as shown in the following illustration.



It often occurs that a company has an admirable mission statement, though it has completely different criteria of personnel evaluation. Such a difference can easily cause misconduct.



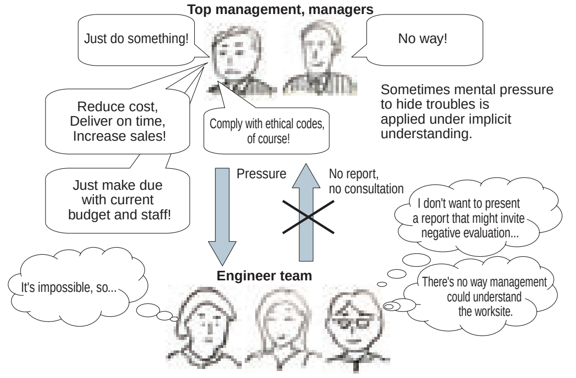
Risk may be permitted to exist if an engineer ignores a problem. When risk is avoidable only by an engineer's independent action but the company has a demerit system, the risk is often overlooked intentionally because the engineer is afraid that he might be evaluated poorly for action. I will explain that later.



One of two risks that I have found in the analysis of incidents is the risk of "just do something", shown on the left side in the figure.

Many companies have ethical codes, but on the other hand, they often demand that employees, "reduce costs, deliver on time, and increase sales!" That causes conflicting values at the worksite because field staff think, "it's impossible, so,..." The other risk is, as shown on the right side in the figure, the risk of "no way!" This means that worksite staff are afraid of negative evaluation and do not want to report what is going on at the worksite; and, when something occurs, the top management cries "no way!" Those risks are quite common.

Ethical Risk Between Top Management, Managers and Engineer Team



So how do we avoid those risks? I will omit specific instances, and introduce rather an example in production technology. Engineers close to the worksite sometimes think that they understand the worksite best, no matter what people in technical administration departments would say. I have found many instances where that can cause situations to get out of control. When a company fails in technical administration closely related to the worksite, such a situation can occur. This is because today's technology is not supported by only design theories, but by empirical knowledge from application at the worksite. I have discovered many instances of such in my analysis.

Case Analysis 1

Lesson: The sense that "we know the details of production technology the best" can be a cause of loosing control.

- Engineers at the production site easily have the sense that "we know the details of production technology the best."
- This is because designing and production technology have a close relation in today's many technologies and production technology includes implicit know-how.
- When the technical control section provides documents or standards that cover only outer characteristics of technologies, or when such a section usually carries out internal audits and reviews that deviate from the essence of the production site, engineers at the worksite tend to have the sense mentioned above.

The other way to avoid typical risks can be found right in the risk of "just do something", mentioned before. In such a situation, engineers think that too honest of a report might put their position at stake. They often try to address an unfavorable technical issue that should be addressed organizationally simply within a limited group.

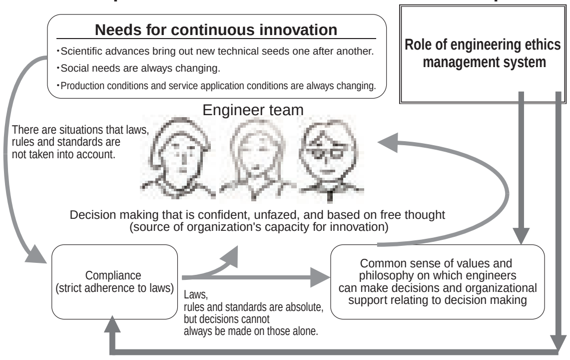
Case Analysis 2

Lesson: "Fear of management" might make an internal audit, review or report system formalistic.

- Technical troubles tend to cause delay of delivery, production stop, budget increase etc. Thus, an organization could build an atmosphere where technical troubles found are to the responsibility of persons in production sections and technical control sections.
- That fosters to a sense of fear that "I might be forced to bear the responsibility if any trouble is found". This sense easily leads to the basis for making indecisive decisions, such as hiding technical troubles (particularly minor ones) and ignoring the situation in spite of expectation of troubles.

In this context, people often question compliance when misconduct occurs; but in a sense, compliance is just the minimum or necessary requirement. Essentially, the best ethical risk control measure is to create an organizational system that enables members to respect a common philosophy that is more simple but more precise, like the Toyota Precepts introduced by Mr. Kobuki, and that protects members as long as they make decisions based on that philosophy. I have reached such a hypothesis through past analyses and I will proceed with further analysis of this hypothesis.

Role of Technical Ethics Management System: Relationship Between Technical Innovation and Compliance



One more point that I like to introduce is a derivative of this hypothesis. In the analysis of misconduct in technical ethics in Japan, I have found that misconduct is often caused not by a true intention to do evil, but by inaction or by ignoring issues. When we think emerging technical changes, I am further afraid that grave situations may be

Emerging Keyword

Inaction

starting to occur.

What I will introduce next is a change in the architectural field, where my background lies; so it may be a bit too much to say that this is the norm. In architecture, we have "robust technology" and "fragile technology". Regarding traditional technology, every one in this field has some know-how on the technical control and desired results can be achieved even by fairly rough work. But "fragile technology" is technologies that require strict control, such as preparing work procedure documents or having meetings in advance, to achieve the acceptable results.

Robust Technology

Robust technologies are methods of building that are considered to be a stable and reliable repertory of technical precedent based on the verification by long-time use.

In other words, robust technologies are methods of building which...
1. ordinary construction engineers understand well through experience, and
2. have robustness that prevents serious failures by some complement function on its own, even when there are some minor errors in communication or work in the process of designing, production, building or use.

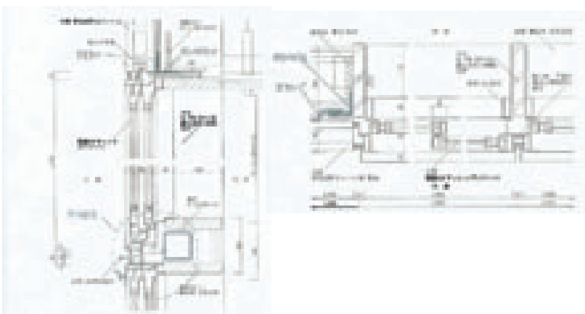
Fragile Technology

This is the opposite concept of robust technology, i.e. methods of building that only a few engineers understand. Those technologies have not been established as a reliable repertory of technical precedent and have a possibility that some errors result in unacceptable failures.

Geometric design of buildings can be learned by training. But functional design of buildings requires higher level of expertise, because it

Example of Fragile Technology

A building method that requires detailed plans and work procedures as well as production control to achieve desired performance and quality



is not easy to distinguish robust and fragile technology.

In extreme cases, accidents may occur when the person in charge proceeds with a project without awareness that the used technology is fragile. This is what possibly occurred in accidents at Toki Messe and Charles De Gaulle Airport, although those are still disputed court cases.

And some technical improvements added to what is regarded as robust technology bring fragile nature in spite of good intentions. In other words, yesterday's robust technology often turns into today's fragile technology.

For example, many of you live in wooden houses. Heat insulation of wooden houses is improving energy conservation, and this is a good trend indeed. But function and fabric of a moisture permeability layer is often not well understood at the worksite. Just as the inside of ski wear gets all wet from perspiration after skiing, poor moisture permeability layer installation causes serious deterioration of life of a timber structured building.

Robust Technology Often Turns into Fragile Technology

・**Condensation inside walls of wooden framed houses**
－Recommended standard specifications changed for higher heat insulation.
－But workers at the site do not understand how to achieve appropriate moisture permeability well.

Those issues fall into my field of expertise. But to end, I will look at the relevance of robust/fragile technologies in railway business.

Railway business is the accumulation of years of empirical knowledge. It is supported by collaboration of a variety of engineers and technicians, and improvements are made continuously date to date. But the technical base is changing. That includes human resources I have covered previously, as well as how communication is carried out and tacit codes. I might be going too far, but what has been regarded as robust technology in railway technologies could be fragile technology now. If so, I think that technical stability requires more than just an increase in standards and in manuals. A system to encourage engineers' independent action, not inaction, is needed to make technologies robust.

I am planning to continue to throw ideas back and forth with JR East for the remaining year of the endowed chair. And through that I hope to obtain some answers to these issues.

Robust/Fragile Technologies Similarity in Railway Business

・**Long accumulation of empirical worksite knowledge**
・**Collaboration by diversified engineers and skilled workers**
・**Continuous improvement**
・**Changing technical base (human resources, practices, communication)**
・**Hence, past robust technologies might be present fragile technologies.**
・**Robustness is not achieved simply by increasing manuals and standards.**