We invited Dr. Akinori Komatsubara, a professor at the Faculty of Science and Engineering of Waseda University, to speak at the 2009 research and development assembly held at the R&D Hall of the Research and Development Center of the JR East Group. Professor Komatsubara delivered a commemorative lecture, where he pointed out that considering “safety secured by people” is becoming increasingly important in considering the relationship between accidents and human factors. The details of the lecture are as follows.

### Accidents and Human Factors

There are three major causes of accidents.

The first is natural causes such as earthquakes, storms and blizzards. While it is difficult to eliminate natural causes, we can prepare for the occurrence and strike of those. Such preparation is done by people, so accidents that occur due to problems in preparation are called man-made disasters.

The second is technical causes. New technologies sometimes include unknown factors, and those could be the cause of accidents. In order to avoid that, careful technical evaluation is required in advance of introducing new technologies. If something missed in such technical evaluations results in an accident, this too is a man-made disaster.

The third is acts by people themselves. A typical example is a traffic accident due to driver error. This is what is called human error.

In considering such accident causes, we see that every accident is without exception directly or indirectly affected by people. Today, industrial systems including railways have become large-scale and energy in those systems has also grown much larger. It is people who design, build, maintain and operate those systems. So, it is thus becoming more important in considering system safety to greatly consider human behavior in each stage of the system.

### Countermeasures Against Human Error

When something expected is not achieved, that is called human error.

Let’s use tightrope walking as an example. The act expected is walking the tightrope from one end to another. If the walker falls off the rope for some reason, that is an error. If the error results in injury of the walker or persons around the walker, it is an incident accident; and if the error results in breaking of the rope or something in the walker’s hand, it is a damage or quality accident (Fig. 1). In order to prevent such accidents, it is necessary to prevent any human error—to take protective actions such as using a safety belt—on the assumption that an error might occur.

Accidents due to human error have been a constant source of worry for people. But, the concept of and approach to preventing them seems to have changed with times.
Fig. 1 Walking across the rope should be accomplished.
If the walker falls off, that is a human error.
If falling causes injury, that is an injury accident.
If something is broken, that is a damage accident.

(1) First Approach: The Era of the One’s Own Risk
The only countermeasure against human errors at one time was probably the person doing something evoking his or her full attention. We say in Japan that “you bring your lunch and injuries yourself”, meaning that you are responsible for dealing with injuries just as you are responsible for bringing your lunch to work. In this way of thinking, if the tightrope walker concentrates and carefully walks on the rope, he or she would never fall off, no matter how thin the rope might be. If the walker falls off, that would be due to his or her own carelessness, so the walker should be punished and trained to correct such an attitude. And making that accident public in the work place would make such a bad practice a good lesson for everyone.

But, humans cannot maintain a high level of attention indefinitely. Fatigue and boredom are normal human physiologic responses. Humans cannot pay attention to more than one thing at once. As such human nature has been revealed by ergonomics, a new idea of essentially questioning the thinness of the rope has emerged. Particularly in industrial systems that are large-scale and employ much energy, safety that relies only on the care of the worksite personnel is just dangerous. In this context, we have begun thinking of “safety that does not rely on people”.

(2) Second Approach: The Era of the Safety That Does Not Rely on People
In this way of thinking, things that can be automated should be thoroughly automated on the assumption that people are not reliable. Things that are technically or economically difficult to be automated should be standardized, defined in manuals and addressed by improving equipment to avoid human error as much as possible. Applying that to the example of tightrope walking, development of a tightrope-walking robot should be considered. If a robot is not feasible, the rope should be replaced with a board, or tightrope walking procedures standardized and the walker fully trained with the manual. A safety net should also be put in place. For railways, automation would be implementing a good signaling system and installing ATC. Standardization would be increasing operability of the driver’s cab and training drivers with a defined driving manual.

(3) Limits of Work Standardization and Equipment Safety
As you know, work standardization and improving equipment safety have resulted in drastic safety improvement. This approach is also easy to manage. If a specific human error often occurs regardless of the person who has done it, that means there is a problem in the work standard or the equipment, so those would simply need to be corrected. If a human error occurs with a specific person, the cause could be insufficient compliance of that person with the manual, so reeducation on the content of the manual would correct the knowledge and attitude of that person. Such management would be most effective for so-called assembly-line production.

Such approaches are, of course, quite important. However, we have recently found problems and limits to that. The following are some of those.

(1) Lack of motivation to work
It may be only natural that a problem with motivation comes up. Ultimately, every move should be as specified by manuals. But, it is human nature to be motivated towards work when working creatively and having discretion or when one can expect to further grow. In other words, people hate being controlled. When problems remained with work standards and equipment that only those at the worksite could understand, those people were motivated by the opportunity to carry out kaizen, or improvement activities. But, as systems become more complete, issues to overcome have become exhausted. In such a situation, kaizen activities could become a source feeling oppressed. Such oppression and lack of motivation towards work will result in a feeling of stagnation in the workplace or even lead to deterioration of the workplace culture of safety. Leaving an appropriate level of self-discretion in work could be better for the workers and consequently for system safety.

(2) Limits to equipment improvement
No matter how important equipment safety is, there are limits to that. One kind is technical limits, and the other is economic limits. Improvement of safely increases logarithmically in relation to the amount of investment. In order to pursue a greater level safety after a certain level has been achieved, a significant amount of investment will be required. In practice, that is becoming difficult from a perspective of the strength of the company. At the same time, we have to consider trade-offs in safety. For example, in order to prevent maintenance workers stumbling on ballast stone, steady walkways should be laid along the track. But, if walkways are laid along every track nationwide, those would increase opportunities for people to enter the trackside for walkway maintenance, which might make the overall system more dangerous. Of course, we should pay attention to safety for those working along the track. Replacing conventional tracks with slab tracks is an effective measure that increases safety, although safety is simply a side benefit if that. Even with slab tracks, however, it would be quite difficult to completely prevent all stumbling.

(3) Huge volumes of manuals
Making work so it is done completely according to manuals is
basically most effective when a person does only one job. In that case, the person has to master only one manual, so the training can be short and there will be little deviation between persons. On the other hand, in jobs where a person has to deal with many types of work, he or she has to learn more manuals and training becomes longer. In such a case, it becomes unclear as to whether the job is learning the manuals or doing the work.

(4) Approach unsuitable to fluctuating work situations
There are many workplaces where the work situation changes moment-by-moment. A typical example is airplane operation. Operation has to be adjusted according to changing wind direction and cloud situations. While there is a prepared standard operation procedure (SOP) to be followed, the pilots have to read between the lines and act at their own discretion on-site. For jobs like that, a finely detailed manual cannot be provided. Even if that were possible, the content would be so vast nobody could learn it all. And if a manual search system could be made so one doesn’t have to memorize the manual, one would often not have the time to search through that.

(5) Possibility of abnormal situations
Though abnormal situations should not occur, they do. In railways, examples could be abnormal sudden weather changes and sudden rolling stock failure. We do have to anticipate those and be trained to deal with them according to a prepared manual. Such an event, however, does not always occur as anticipated. In such circumstances, it is important to minimize the damage by timely and flexible response of the people involved.

In light of that, it has been advocated that we frankly recognize the problems and limits of work standardization and equipment safety (which we should still promote), and that we think of safety by human flexible actions. That concept is developing in Europe into resilience engineering, a new category of human factors. This could be called the third approach.

4 Responsibility and Accountability
While this subject digresses somewhat from the main topic, work always involves responsibility and accountability, as it is not play. For railways, that is providing aspects such as safety, punctuality and amenity to passengers.

(1) Responsibility
Responsibility is meeting (responding to) the expectations of the other party. For public transport, no accident should occur for any reason as passengers rely on the operator and trust it with their lives. Thus, the all involved are required to be diligent to prevent such incidents.

(2) Accountability
While responsibility is important, it cannot be left completely to individuals. Passengers will not rely on an operator that simply brags of its diligence. An operator has to take systematic actions to prevent accidents. Only when the operator can account for those actions with confidence, will passengers rely on it. Accountability means that one can swear as to how actions have been properly taken.

5 What to Account for?
Now let us think of what to account for in accountability. With the second approach, we would account for what we have done to make workers strictly adhere to work standards. In other words, we would account for the results of plan-do-check-act (PDCA) activities based on the data of human errors and near misses, using that to review weakness in the safety of equipment and the thoroughness of manuals. Accounting for such would lead to further automation, facility improvement and thoroughness of manual training.

On the other hand, in the third approach, we would account for the method of personal improvement that the organization has taken and the PDCA method for that. In order to be able to read between the lines and think and act on one’s own initiative, high qualification of individuals are required. Actions by one with low qualification are far from being safe. So, what then does high qualification mean?

6 Improving Individual Qualification
It is said that good personal practices require the following four items (Fig. 2).

(1) Mental and physical health
(2) Technical skill: Skill and knowledge directly related to the job
(3) Non-technical skill: Abilities to smoothly perform a job such as communication skill and attentiveness. This is Crew Resource Management (CRM) skill in the aviation industry
(4) Attitude: Sensitivity to danger and pride and responsibility as a professional

In the third approach of safety relying on people, it is clear that safety cannot be achieved without high qualification in all of the above-mentioned four items. Taking systematic actions to improve
those four is required. Particularly in this age when young people's sensitivity to risk, communication skill and basic skills are said to have weakened, it will probably be an issue to take the necessary PDCA steps to improve those.

There are four important points in thinking of safety that relies on people.

First of all, the foundation lies in the second approach (thorough automation of what can be automated, on the assumption that people are not reliable). It makes no sense to rely on people without automation and equipment when those could secure safety. Safety that relies on people has no advantage over safety that doesn't rely on people.

Secondly, it is necessary to manage systematically to improve individual qualification as previously explained.

The third point is not to discipline the person who made a human error. This is because human error due to mistakes in reading between the lines can be pointed out only in hindsight. One can say later, "what if the person had done such-and-such", but that person made the best judgment he or she could think of at the time. If that person thought it was wrong, he or she would have not made such a judgment. Thus, those who make human errors should not be disciplined, while it is still important to learn from supposing "what if". If disciplined, people would become intimidated and avoid making decisions, believing that it's better not to be involved.

The last thing is to realize and be cautious of the tendency to fall into a model of thinking that failure to correctly read between the lines in safety relying on people is the fault of the person. There is a risk of returning to the era of believing that "you bring your lunch and injuries yourself" in the first approach. We have to recognize that and create a culture of avoiding it.

Safety is something everyone hopes for. Yet to bring that about requires strategy, tactics and skill according to the actual situation of individual organizations and systems. For safety and human factors in railways, I think it is time to review the measures taken up to now and develop a new perspective of strategy.

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