A Study on Safety Awareness by Risk Avoidance in Building Facilities & Practicability of Risk Prediction Sheets under ISO45001

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Abstract. The study discussed in this paper aims to prevent hazards and risks which may occur during the installation of building facilities, by making the most of risk prediction training sheets (hereafter, risk prediction sheets) and analyzing the degree of safety awareness among trainees. This survey has been carried out for nearly five years, in which supervisors and workers who are engaged in equipment installation were tested with illustrated risk prediction sheets depicting typical equipment installation activities. And we suggested the practicability of risk prediction sheets under ISO45001.

1. Introduction
Uda and Tanaka[1] published their paper under the title, “Trials of risk prediction sheets for installment/maintenance of building facilities and important points of safety management in Japan,” in the proceedings of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (SHASE). From the time of their experimental stage, no relevant studies were carried out. Thus, in order to develop the study further on an extensive scale, the five-year research was conducted by distributing illustrated risk prediction sheets to supervisors and workers engaged in installation of building facilities, after in-depth discussions among the safety-related subcommittee members of SHASE construction and maintenance committee.

The research result is analyzed in this paper as a practical study for the prevention of risk during installation of building facilities. The main purpose of this study is to present and analyze effective safety activities, training methods, procedures for risk management/analysis/evaluation in relation to building facilities, which will be integrated into safety education and daily practices, and eventually lead to the reduction of accidents.

And we suggested the practicability of risk prediction sheets under ISO45001.

2. Risk prediction (kiken yochi: KY) sheets

2.1. Outline
Before putting KY sheets to practical use, types of accidents in the installation works of building facilities were analyzed based on the latest official statistic data. As in building construction works, accidents caused by fall from a height and flying/falling objects made up a large proportion (50.6% in building construction works and 43.6% in building facilities from 2010 to 2015). Besides, accidents
caused by electricity and explosion were found peculiar to installation works of building facilities (0.2% in building construction works and 1.5% in building facilities from 2010 to 2015) [2][3]. Because KY activities are generally integrated into building construction works in the site, KY sheets with emphasis on construction works and those focusing more on building facilities were employed.

These sheets provide KY training for workers, who are required to guess and freely describe dangers lurking in the illustrated work scenes. As one of KY activities in the construction site, appropriate sheets relevant to the day’s works are distributed among workers at a meeting to let them point out potential dangers and consider appropriate measures. In addition to blank answer sheets, those written model answers on were prepared so that workers can be self-enlightened by comparing their answers with model answers.

The four KY sheets are related to the installation of building facilities are analyzed in this paper. They are the sheet No. 1 (Bringing a duct into a roof-space; No. 2 (Removal of a water-cooled air conditioner); No. 3 (Manhole installation); and No. 4 (Work with furnishings). Model answers for the works illustrated in Figures 1 to 4 are indicated in Tables 1 to 4, respectively.

2.2. KY sheet No. 1 (Bringing a duct into the roof-space)
The Figure 1 is the KY sheet No. 1 (Bringing a duct into the roof-space) which depicts a duct for a ventilating and air-conditioning system being brought in. Its model answers are shown in Table 1.

| No. | Model answers |
|-----|---------------|
| ①  | Lighting fixed at a wrong place hampers manual work |
| ②  | A bus bar not cured properly above the duct route may |
| ③  | Workers wear no safety belt. |
| ④  | Workers do not tighten a helmet chin strap. |
| ⑤  | Work on a stepladder is unstable. |
| ⑥  | Wiring is unsecured |
| ⑦  | An earth leakage breaker is out of use |

2.3. KY sheet No. 2 (Removal of a water-cooled air conditioner)
Figure 2 depicts the scene where a duct is disjoined after a cooling water pipe and a humidifier water pipe are disconnected from the main lines for the removal of a water-cooled air conditioner. In addition to safety measures, respondents are expected to be familiar with construction techniques such as plugging. Its model answers are shown in Table 2.

| No. | Model answers |
|-----|---------------|
| ①  | Pipe plugs are not fastened. |
| ②  | A curing sheet is not applied to doorway. |
| ③  | The stepladder should not be sit astride. |
| ④  | The stepladder won't latch properly. |
| ⑤  | The stepladder is not skid-proof. |

Figure 1. KY sheet No. 1 (Bringing a duct into the roof-space)

Figure 2. KY sheet No. 2 (Removal of a water-cooled air conditioner)
2.4. KY sheet No. 3 (Manhole installation)
Figure 3 depicts the scene where a manhole lid and frame is carried on a cart for the installation of a cooling water tank. In this scene, some materials and tools for another work remain laid down. Thus, respondents are expected to have a wider vision. Its model answers are shown in Table 3.

| No. | Model answers                          |
|-----|----------------------------------------|
| ①  | Workers wear no goggles.               |
| ②  | A curing sheet is not applied.         |
| ③  | A safety barrier must be strongly-built.|
| ④  | A cart won’t stop on the downslope.    |
| ⑤  | The ramp is constructed at a wrong place.|
| ⑥  | The work section is not put in order.  |
| ⑦  | An earth leakage breaker is out of use.|
| ⑧  | Wiring is unsecured.                   |

2.5. KY sheet No. 4 (Work with furnishings)
Figure 4 depicts the partial remodeling in an office where one worker is tightening a hang bolt into the ceiling and the other worker is refurbishing an illumination route. In addition to general safety measures, knowledge for the prevention of electrical accidents is tested. Its model answers are shown in Table 4.

| No. | Model answers                          |
|-----|----------------------------------------|
| ①  | Live-line working is not permitted.    |
| ②  | Workers wear no rubber-insulated gloves.|
| ③  | An earth leakage breaker is out of use.|
| ④  | Wiring is unsecured.                   |
| ⑤  | Drilled chips fly over the face.       |
| ⑥  | Work on a stepladder is unstable.      |
| ⑦  | The stepladder is not skid-proof.      |
| ⑧  | A metal-sensing cable reel is out of use.|

3. Introduction of KY sheets to installation work sites of building facilities

3.1. Outline
For the purpose of comprehending the degree of KY ability among respondents by occupation, length of experience and age, KY training was given to supervisors and workers by using KY sheets discussed in Section 1. The survey was conducted on supervisors and workers from building contractors and their affiliates. The numbers of participants are shown in Tables 5 and 6. As the tables show, the total number of participants was 943 and the ratio of supervisors to workers was 1:1.3.

Among all the supervisors, 81 persons were new employees with no experience between the ages of 20 and 34. The remaining 32 supervisors were between the ages of 20 and 64, and the length of their experience ranged from several months up to 41 years. The workers were between the ages of 21 and 58, and the length of their experience ranged from several months up to 42 years. At the construction sites or during group training, the supervisors and workers were briefed about the objective of this
project, and given the explanation of how to fill in the sheets with sample answers. Then, each person was provided with two or three sheets randomly and allowed to write free answers. In order to give the participants enough time to think, a 30-minute time limit was set equally as a rule. The filled-out sheets were marked on a basis of 100 points as a perfect score which would be achieved if all the model answers were produced.

Table 5. The number of participants by length of experience in work sites

| Age          | Supervisors | Workers |
|--------------|-------------|---------|
| Inexperienced (20-34) | 81          | 132     |
| 20-29        | 115         | 132     |
| 30-39        | 76          | 121     |
| 40-49        | 61          | 106     |
| 50-59        | 58          | 103     |
| 60 and older | 15          | 75      |
| **Total**    | **406**     | **537** |

Table 6. The number of participants by age (unit: person)

| Years of experience work sites | Supervisors | Workers |
|---------------------------------|-------------|---------|
| Inexperienced                   | 81          |         |
| 5 or less                       | 108         | 145     |
| 6 - 10                          | 72          | 118     |
| 11 - 20                         | 63          | 106     |
| 21 - 30                         | 48          | 91      |
| 31 and longer                   | 34          | 77      |
| **Total**                       | **406**     | **537** |

3.2. Analytical results of the KY sheets introduced to the installation sites of building facilities

Under the procedure stated in Section 2.1, a total of 1024 sheets were completed: 81 sheets by inexperienced supervisors; 406 sheets by experienced supervisors; and 537 sheets by workers.

Analytical results by occupation, length of experience, and age are discussed below.

3.2.1. Analytical result by length of experience

The workers’ score increased as the years of their experience built up. It is assumed that the long experience has developed their empirical knowledge, which is eventually shown as the KY ability. In the case of the supervisors, however, it cannot be simply said that their scores increase as the length of experience extends. As the work load varies depending on the section and the number of foremen, the length of experience is not necessarily reflected in the KY ability of supervisors. The relatively high scores among those with limited experience of up to five years were assumed to result from daily safety activities including patrols.

3.2.2. Analytical result by age

It shows the tendency of scores increasing with age. The score among the experienced supervisors between the ages of 40 and 49 little increased their score in comparison with that of the workers in the corresponding age group, which may be attributed to their inattentiveness as they became use to KY training.

4. Survey results

4.1. Bringing a duct into the roof-space (Sheet No. 1)

Figure 1 shows the illustrated question. For this question, seven model answers listed in Table 1 were prepared. The resultant accuracy rates are shown in Table 7. A tendency and characteristics of answers to this question are discussed below.

Most of the experienced supervisors correctly pointed out two items “③ Workers wear no safety belt” and “④ Workers do not tighten a helmet chin strap” above the accuracy rates of 91.5% whereas those among the workers were also high ranging from 82.3 to 93.8% (88.1% on average). According to the results, it seemed that the workers developed safety awareness when it came to direct body protection and the experienced supervisors had a strong sense of responsibility for protecting their workers under safety management.
4.2. Removal of a water-cooled air conditioner (Sheet No. 2)

Figure 2 shows the illustrated question. For this question, five model answers listed in Table 2 were prepared. The resultant accuracy rates are shown in Table 8. A tendency and characteristics of answers to this question are discussed below.

(1) The accuracy rates of the answer “① Pipe plugs are not fastened” were as low as 33.6% among the inexperienced supervisors. In the meantime, the accuracy rates of the same answer among the experienced supervisors and the workers were 66.2% and 59.5%, respectively.

(2) The accuracy rate of the answer “⑤ This result indicates that their safety awareness about stepladders was little as they had no experience in the work site. However, the accuracy rates of the same answer were 57.5% among the inexperienced supervisors, 61.1% among the workers and 68.4% among the experienced supervisors, showing their high safety awareness about stepladders.

4.3. Manhole installation (Sheet No. 3)

Figure 3 shows the illustrated question. For this question, eight model answers listed in Table 3 were prepared. The resultant accuracy rates are shown in Table 9. A tendency and characteristics of answers to this question are discussed below.

Answers to this question given by the experienced supervisors were “⑥ The work section is not put in order,” “① Workers wear no goggles,” and “② A curing sheet is not applied” in decreasing order between the rates of 62.2 and 65.2% (63.8% on average), signifying intentions of the experienced supervisors regarding work plan and management for safety.

4.4. Work with furnishings (Sheet No. 4)

Figure 4 shows the illustrated question. For this question, eight model answers listed in Table 4 were prepared. The resultant accuracy rates are shown in Table 10. A tendency and characteristics of answers to this question are discussed below.

(1) The accuracy rates of answers “③ An earth leakage breaker is out of use,” “④ Wiring is unsecured,” and “⑥ A metal-sensing cable reel is out of use” were particularly low. With experience, the accuracy rate among the supervisors increased: the inexperienced supervisors between the accuracy rates of 27.7 and 48.3% (34.8% on average) and the experienced supervisors between the rates of 52.1 and 56.8% (54.4% on average).

(2) The accuracy rate of “② Workers wear no rubber-insulated gloves” among the workers was 51.3%, which only exceeded the rate of 48.2% achieved by the experienced supervisors. This manifests the consciousness of ensuring the safety among the workers when direct contact with materials is inevitable.

5. Practicability of risk prediction sheets under ISO45001

Uncover why ISO45001 has the potential to be a real game changer for millions of workers (and workplace health hazards) around the world. The framework of ISO45001 in the catalog[6] was published by the ISO headquarters. As the diagram indicates, the ISO working groups plan to add detailed standards for dangerous works successively as ISO45002 and ISO45003.

In Japan, safety and health activities prescribed by the Ministry of Health, Labour and Welfare (MHLW) in its guidelines have been seriously carried out as a matter of daily routine, having produced satisfactory outcomes for the prevention of industrial accidents. Table11 demonstrates the result of questionnaire surveys conducted in 2017 by the Public-Private Council for Safety Measures and the Japan Industrial Safety and Health Association.

The contents in (1) are items which are integrated into safety and health targets/plans and managed to operate through the plan-do-check-act (PDCA) cycle in the workplaces surveyed. Safety and health activities peculiar to Japan, such as hiyari hatto (near-miss) prevention activities and KY (kiken yochi or risk prediction) activities, are set as safety and health targets/plans and managed by many workplaces. The contents in (2) are safety and health activities that the workplaces rated as effective.
Table 7. Sample model answers for the sheet No. 1 (Bringing a duct into the roof-space) (Accuracy rate: %)

| No. | Items                                                                 | Workers | Experienced supervisors | Inexperienced supervisors |
|-----|----------------------------------------------------------------------|---------|-------------------------|--------------------------|
| ①  | Lighting fixed at a wrong place hampers                             | 76.3    | 89.5                    | 21.2                     |
| ②  | A bus bar not cured properly above the duct route may lead to electric shock. | 64.6    | 78.5                    | 22.2                     |
| ③  | Workers wear no safety belt.                                       | 93.8    | 95.7                    | 35.0                     |
| ④  | Workers do not tighten a helmet chin strap.                         | 82.3    | 91.5                    | 56.6                     |
| ⑤  | Work on a stepladder is unstable.                                  | 63.6    | 68.1                    | 58.7                     |
| ⑥  | Wiring is unsecured.                                               | 52.3    | 60.2                    | 22.3                     |
| ⑦  | An earth leakage breaker is out of use.                             | 52.2    | 54.0                    | 25.5                     |

Table 8. Sample model answers for the sheet No. 2 (Removal of a water-cooled air conditioner) (Accuracy rate: %)

| No. | Items                                                                 | Workers | Experienced supervisors | Inexperienced supervisors |
|-----|----------------------------------------------------------------------|---------|-------------------------|--------------------------|
| ①  | Pipe plugs are not fastened.                                         | 59.5    | 66.2                    | 33.6                     |
| ②  | A curing sheet is not applied to doorway.                            | 60.4    | 69.3                    | 39.8                     |
| ③  | The stepladder should not be sit astride.                            | 63.7    | 76.3                    | 52.1                     |
| ④  | The stepladder won’t latch properly.                                | 59.4    | 64.0                    | 60.2                     |
| ⑤  | The stepladder is not skid-proof.                                   | 61.1    | 68.4                    | 57.5                     |

Table 9. Sample model answers for the sheet No. 3 (Manhole installation)

| No. | Items                                                                 | Workers | Experienced supervisors | Inexperienced supervisors |
|-----|----------------------------------------------------------------------|---------|-------------------------|--------------------------|
| ①  | Workers wear no goggles.                                             | 56.6    | 63.9                    | 27.8                     |
| ②  | A curing sheet is not applied.                                       | 55.8    | 62.2                    | 36.3                     |
| ③  | A safety barrier must be strongly-built.                             | 48.8    | 56.1                    | 29.8                     |
| ④  | A cart won’t stop on the downslope.                                 | 49.3    | 59.7                    | 29.6                     |
| ⑤  | The ramp is constructed at a wrong place.                            | 48.8    | 55.3                    | 26.8                     |
| ⑥  | The work section is not put in order.                                | 57.1    | 65.2                    | 36.8                     |
| ⑦  | An earth leakage breaker is out of use.                              | 48.4    | 54.2                    | 25.4                     |
| ⑧  | Wiring is unsecured.                                                | 47.0    | 54.6                    | 25.6                     |

Table 10. Sample model answers for the sheet No. 4 (Work with furnishings)

| No. | Items                                                                 | Workers | Experienced supervisors | Inexperienced supervisors |
|-----|----------------------------------------------------------------------|---------|-------------------------|--------------------------|
| ①  | Live-line working is not permitted.                                 | 47.7    | 50.9                    | 45.9                     |
| ②  | Workers wear no rubber-insulated gloves.                            | 51.3    | 48.2                    | 45.8                     |
| ③  | An earth leakage breaker is out of use.                              | 48.1    | 52.1                    | 28.5                     |
| ④  | Wiring is unsecured.                                                | 52.6    | 56.8                    | 27.7                     |
| ⑤  | Drilled chips fly over the face.                                     | 64.4    | 69.8                    | 61.6                     |
| ⑥  | Work on a stepladder is unstable.                                    | 62.9    | 68.2                    | 61.3                     |
| ⑦  | The stepladder is not skid-proof.                                    | 60.6    | 66.1                    | 59.4                     |
| ⑧  | A metal-sensing cable reel is out of use.                            | 51.9    | 54.3                    | 48.3                     |

KY activities and 4S activities specific to Japan which have been conventionally observed are highly evaluated by many workplaces.

KY training sheets introduced in this paper have proved effective as part of KY activities. In Japan, they are adopted by JISQ45001 which is compatible with ISO45001. Thus, it seems plausible that they will be introduced as an international concrete tool under ISO45001.
Table 1. Effectiveness of safety and health activities
(Retrieved from the website of Japan Industrial Safety and Health Association)

| (1) Activities integrated into safety and health plans | (2) Activities rated as effective |
|-----------------------------------------------------|---------------------------------|
| 1. Risk assessment                                  | 1. KY activities 93%            |
| 2. Safety and health patrols                        | 2. 4S activities 92%           |
| 3. Safety and health committee                      | 3. Meetings (e.g. at the start of work) 91% |
| 4. Safety and health education                      | 4. Risk assessment 90%         |
| 5. Hiyari Hatto prevention activities               | 5. Safety and health patrols 89% |
| 6. KY activities                                    | 6. Safety and health committee 89% |
| 7. 4S activities                                    | 7. Hiyari Hatto prevention activities 88% |

Safety and health activities specific to Japan have been conventionally observed and highly evaluated by many workplaces.

6. Conclusion & Future issues

In this practical study, the degree of safety awareness in the installation of building facilities was analyzed by making the most of KY sheets which depict typical work scenes. In this paper, results of the five-year survey on the KY sheets distributed to supervisors and workers who were engaged in the installation of building facilities were analyzed in order to comprehend the degree of their KY ability by occupation, length of experience and age.

In this paper, the trial result of KY sheets and the feasibility of KY sheets to be adopted under ISO45001 are discussed. One of our future tasks is to develop KY sheets for major industries applicable to any countries by using common illustrations so that we can compare results between countries, industries, or occupational categories. ISO45001 is an occupational safety and health management system in the broad sense. In Japan, an approach to the reduction of overtime work, which is one of the work style reforms, has been promoted by the national government. For workers to be sound in mind and body, it is desirable to make most of KY sheets under feasible plans.

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