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# A Logical Hazard Identification Method in Workplace

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The quality of hazard identification has a significant impact on the quality of overall risk assessment and occupational accident prevention in workplace. Currently accepted hazard identification approaches tend to rely on knowledge of previous accidents, experience of the task, and participants' imagination, although hazard identification itself is most important for new tasks and novices who do not have experiences of the same or similar tasks.
This paper outlines a logical hazard identification method based on a concept for object-based energy analysis as a tool that does not require experience, knowledge of tasks, or imagination. The method is derived from a physical principal and the analysis of occupational accidents. This method is expected to enable users to identify hazards effectively and easily, and contribute to successful risk assessment.

## 1. Introduction

Risk assessment in workplace is an important and essential process for preventing occupational accidents. Adequate risk assessment helps workers reduce health and safety risks, and raises worker awareness of risks. Good risk assessment also contributes to the enhancement of a safety culture (Cooper, 1998). In the European Union, the European parliament adapted Directive 89/391, a "Framework Directive" for the implementation of risk assessment in workplace (European Agency for Safety and Health at Work, 1989), and the European Union member states have implemented this directive into their national laws. Meanwhile, in Japan, the Industrial Safety and Health Act was amended in 2006 to incorporate risk assessment as one of the added requirements that an employer shall endeavour to investigate danger in workplace (Japan Industrial Center for Occupational Safety and Health, 2006). The aim of this amendment is to encourage stakeholders to conduct risk assessment; safety in workplace was formerly maintained chiefly by conformance with detailed codes and specifications. Risk assessment encourages stakeholders to focus on the hazards and risks that really matter in their workplaces rather than rely on the generic compliance approach.
In risk assessment, hazard identification represents the first step as a means of managing risks. Risk estimation and risk evaluation are conducted for each hazard identified at the beginning of a risk-assessment process. These risks are then reduced depending on their consequences and frequencies. Considering the flow of risk assessment, the quality of hazard identification determines the quality of the overall risk assessment. If a hazard is overlooked in the hazard identification process, the hazard will be left unaddressed and can subsequently cause harm to workers.
There are some commonly used approaches for hazard identification (Ericson, 2005). One approach is to use hazardous element and component checklists based on previous experience (Rasmussen, 1989). The use of a checklist can help participants to screen problems in the workplace. A checklist is particularly useful when the requirements are clear – such as compliance with the rules, regulations, and standards (Gürcanli and Müngen, 2009).
Another approach is to use past experience in similar systems to assist in hazard identification. One example is the Job Safety Analysis system reported by Raveggi and Mazzetti (2010), in which the histories of accidents and any "near misses" are needed. The use of a database falls into this approach. Many

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companies have made efforts to collect accident data for a database so that stakeholders can access previous accident' information and reduce the chance of reoccurrence of the same or similar accidents.
There is another approach to create a possible scenario resulting in an accident. In the process of developing a scenario, the participants can identify the associated hazards. The major feature of the scenario-based approach is the better-defined options as a technical issue becomes narrower and more technical (Berkhout, et.al., 2002).
Hazard Identification Activity commonly accepted in Japan can be categorized as a scenario-based approach (Japan Industrial Safety and Health Association, 2006). In the generic process of the activity, the participants create an accident scenario by completing a sentence with words or phrases related his/her task, possible accidents, and consequences; one of the framework is , "When I (we) conduct [a task], [an accidental event/mishap] happens, then [an injury / a harm to a worker] occurs". During the session, participants need to imagine the details of what they will do at the site and in the environment of the task. In previous research, 74.1% of companies consider this activity effective for preventing occupational accidents. The rate of lost-worktime injuries was reduced over 5 years after averaging results for 658 companies (Japan Industrial Safety and Health Association, 2005).
In these well-accepted hazard identification approaches, workers are encouraged to consider what kind of accident they will encounter by using their experiences, knowledge, and imagination (Crawley and Tyler, 2003). Furthermore, most of the scientific research effort for the improvement on safety has been devoted to risk evaluation and estimation, and the effort related to hazard identification has been made to compile experiences from accident cases.
That poses a dilemma because risk assessment is especially needed for new tasks and by inexperienced workers. Moreover, hazards in the workplace are sometimes not apparent in new cases. Even though the participants demonstrate their imagination to create a scenario or envisage a hazard, imagined hazards might be unrealistic. Under the current circumstances of experienced personnel retiring and rapid turnover, a logical method independent from experiences and imagination is required to lead workers to recognize potential hazards in their workplace.
To fill the gap due to the lack of experience, a logical hazard identification method with 3+1 rules has been developed based on the concept of object-based energy analysis. This paper outlines the methodology and the result of the validation of the method.

## 2. The concept of object-based energy analysis and 3+1 rules for hazard identification in workplace

While the commonly used approaches highlight behaviors and actions in the workflow, the object-based energy analysis brings attention to any objects in the working environment. The concept of object-based energy analysis is deductive reasoning from simple physical principles underlying the accident. The physical principles are expected to be easily applied by inexperienced workers and provide unbiased consideration.
The object-based energy analysis is reduced to four rules named the "3+1" rules, for logical hazard identification.

### 2 .1 The 3+1 rules

The hazard identification method consists of four rules: three rules mainly describing the nature of the "energy" of an object in the workplace; and one rule related to the nature of the "trigger". These four rules are as follows:

*Five types of energy cause accidents*

In an occupational accident, workers are unexpectedly subjected to an external force greater than their physical resistance. This rule represents the principle that the physical energy of an object is released and leads to an accident by distorting, causing disorder, or destroying facilities, equipment, and people. In this rule, energies are categorized into five types: kinetic energy; potential energy; chemical energy; thermal energy; and electrical energy. Nuclear and radioactive energy are excluded from this definition. Specific types of injuries and damage can be assigned to each type of energy. One point that should be noted is that humans are also regarded as objects in this concept. For instance, a moving worker gains kinetic energy and is subject to the analysis.

*Each type of energy can convert into other types*

As with the law of conservation of energy in physics, energy can change forms until it is consumed in an accident. For instance, electric energy can directly cause an electric shock to kill workers, and can heat up facilities to cause burns from thermal energy. This rule also implies a transfer of energy from one object or worker to another.

*A trigger is required to activate the energy to cause an accident*
Workers can remain unharmed despite the fact that an object in the workplace has energy. The energy of an object, however, can be released and harm a worker under “specific conditions”. A “trigger” is a condition that can activate the hazardous release of latent energy. For instance, “decreased distance” is a trigger for thermal energy; i.e., thermal energy is harmless if the energy source is distant from objects and workers. The energy is activated and becomes harmful when the distance between the energy source and objects/workers decreases.
The above three rules represent the nature and behavior of energy. In addition, another rule can be described as follows.

*The Performance of triggers can change over time*
Time can change the effectiveness of triggers in both the short and long terms. The trigger “distance” can change in the short term or over time; e.g., someone or something can change the position of equipment intentionally or unintentionally. In the long term, facilities decay, deteriorate and decrease in strength. The possibility of a trigger shifting toward the dangerous side always needs to be considered.

### 2.2 The validation of 3+1 rules
The effectiveness of the object-based energy analysis was measured by using pictures depicting an activity in a construction and a manufacturing site. The participants comprised 7 undergraduate university students and 5 graduate students (7 men, 5 women). The mean age of participants was about 23 years.
In the experiment program, participants looked at five pictures ordered in a random manner and identified hazards for each picture. They took 5 min for each picture. Instruction regarding the object-based energy analysis was then given for about 30 min using a PowerPoint file with a fixed script that the examiners read aloud. It was followed by a written 10 min examination to evaluate the level of understanding. Participants were then asked to identify hazards in another five pictures for 25 min in total. Participants were divided into two groups. The five pictures that one group viewed before instruction were used for the other group after instructions were given. In each group, different pictures were used before and after instructions were given. Scores for each subject were calculated as the sum of the numbers of identified hazards in five pictures for the first (before instruction) and second (after instruction) sessions. Scores for before instruction and after instruction were compared.
The results of the comprehension test to evaluate the level of understanding did not show any specific difficulties or problems in understanding the concept among subjects. Participants showed a relatively firm grasp of the fundamental natures and functions of each energy and trigger.
The average scores were 2.7 before the instruction and 3.1 after the instruction. A paired t-test was used for comparisons and the effectiveness of instruction was estimated. Significant differences in scores were observed using a paired t-test ($t=2.66$, $df=11$, $p<0.05$), allowing us to test the null hypothesis in this study of no difference between before and after instructions were given. Based on the results with statistically-significant increase, the null hypothesis was rejected, indicating that these instructions worked to improve the score.

## 3. Examination of object-based energy analysis with cases

### 3.1 Case applications and derived triggers
The rules were actually applied to 452 cases from databases (Japan Advanced Information Center of Safety and Health), books(Construction Contractors Association,1993, 1994 , Japan Industrial Safety and Health Association, 1994, 1995a,b, 1996, 1997), and websites (Japan Industrial Safety and Health Association, Health and Safety Executive) ranging from 1993-2011. In each case, energies causing accident was determined and 17 triggers were identified (Table 1) .

### 3.2 Format of a hazard identification session
In the hazard identification session using object-based energy analysis, participants selected and focused on an object or a worker rather than a procedure or a scenario of their task. Then they considered what kind of energy the object or worker possessed. A worker can be regarded to possess kinetic energy when he/she is moving and/or potential energy when he/she is at height (or at higher level than the surroundings). Because it is possible that an object possesses more than one type of energy, participants could separately consider each mode of energy of the object.

The energy can be determined by participants with a scientific background or a knowledge of physics. Even participants without a scientific background can select proper energy accompanying the object because the modes of the object with certain energy can be expressed with energy keywords (Table 2). Energy keywords are helpful to select suitable energies in the object and the energy keywords directly link to accidents that will occur when the latent energy is released.

*Table 1: Triggers corresponding to energy*

| Applicable Energy | | | | | Triggers |
|---|---|---|---|---|---|
| Potential | Kinetic | Chemical | Electric | Thermal | |
| X | X | X | X | X | Decreased distance |
| X | X | | | | Insufficient grip |
| X | X | | | | Imbalance |
| X | X | | | | Fixture malfunction |
| X | X | | | | Disintegration / Collapse |
| X | | | | | No/Unstable handrail/fence |
| X | | | | | Unstable floor/ground |
| | X | | | | Discord movements between more than one object |
| | X | | | | No/Unstable cover/hood/housing |
| | X | | | | External force input greater than expectation |
| | X | X | | | Flaw of confinement |
| | | X | | | Change in quantity/concentration |
| | | X | | | Decrease distance toward ignition source |
| | | X | | | Temperature rise |
| | | X | X | X | Flaw of insulator |
| | | | | X | Expansion/Distortion |
| | | | X | | Contact with electrical current |

*Table 2: Energy keywords*

| Energy | Energy keywords | Possible accidents |
|---|---|---|
| Potential | Heavy, going to be heavy | Fall, Crush |
| | High, going to lift | Fall, Crush |
| | Higher than the level of the surround | Fall, Crush |
| Kinetics | Pile up/ Build up | Collapse |
| | Move horizontally / can move horizontally | Sever, Shear, Crush |
| | Move vertically / can move vertically | Crush |
| | Rotate / can rotate | Entangle, Impact by flying fragments, Abrasion |
| | Pivot / can pivot | Crush |
| | Increase load | Crush |
| | Increase internal pressure | Crush |
| Chemical | Chemical substances | Explosion, poisoning, chemical injury |
| Electrical | Current applied | Electric shock |
| Thermal | Hot, can get hot | Burn |
| | Cold, can get cold | Cold injury |

In the hazard identification session, participants then consider possible triggers that can be applied to the object. Because the “triggers” in Table 1 are abstract and used as guidewords, the triggers are therefore capable of wide application in various workplace conditions.

**3.3 Benefits of the hazard identification method based on object-based energy analysis**

In the hazard identification session, participants considered objects rather than procedures. This enabled the scope of their activity relating to a task to extend further and promote awareness of surroundings as well as the work area actually applied to their procedures. If they focused only on the procedures, they tend to consider only objects used for the procedures. Accidents, however, occur often through interaction with nearby workers or objects used in others’ tasks. That means the method can be useful for someone who is in charge of safety intervention covering various areas because this method is not task-specific.

This object-based hazard identification approach is expected to broaden the scope compared to the scenario-based approach. The scenario-based approach allows participants to imagine what will happen in detail. On the other hand, it narrows the range of thought. For instance, in our investigation, a safety manager who wished to remain anonymous revealed that his company identified about 20% of hazards resulting in accidents with scenario-based hazard identification. The rest had been overlooked during the regular risk assessment.

## 4. Conclusion

Commonly used approaches highlight the importance of experience, knowledge of previous accidents and imagination. However, they can sometimes derive limit the scope of hazard identification and lead to oversights in the risk assessment.
This article describes the concept of object-based energy analysis that is deducted from physical principles. The object-based energy analysis is reduced to four rules for logical hazard identification. The four rules are:
- Five types of energy cause accidents
- Each type of energy can convert into other types
- A trigger is required to activate the energy to cause an accident
- The performance of triggers can change over time

The effectiveness of this approach was measured in an experiment with brief instructions that indicated improvements among participants for finding hazards in pictures compared to the results using participants' imagination alone. The present approach is thought to be beneficial in the following respects: it uses simple rules, broadens the scope, and is independent from experiences.
The results of the validation can be mentioned to indicate the effectiveness of this method for at least students, who have less experience of work at a construction and a manufacturing site. Further investigation is needed to prove the effectiveness of the method for workers working at the workplace, where many kinds of hazards exists, and clarify the validity and utility of this method.
The quality of hazard identification has a considerable influence on risk assessment, can reduce the number of injuries, and can ultimately improve the level of safety in the workplace.
By using the concepts presented in this article, participants will gain a better understanding of the nature of occupational accidents, be better prepared, and be better able to deal with novel tasks. This concept supplies a systematic approach that can work in a complementary manner with currently accepted approaches such as checklists and the scenario-based approach.

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