XML Schema for Implementing Safety Management System in Shipbuilding

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***Abstract*—With a rising demand for developing deep sea resources recently, that for offshore plant construction are getting greater. Accordingly, plant owners request more for a safety management system in the process of offshore plant building. Thus, it is required that a safety management system is built for each shipyard or offshore plant building project. In order to develop a safety management system, it is important that risk factors in each task should be properly identified. Most information with respect to work processes or risk factors can be commonly applicable. But, most of the safety management system is developed upon an assumption that such information is implicitly inherent within the system. In this respect, to ensure that the key information, such as task and hazard information for building safety management system is not inherent within the system, we defined XML (eXtensible Markup Language) Schema to ensure that such information can be expressed in standardized-format XML. By doing so, even if risk and work process contents change, XML files can be used after redefined - without changing safety management logic of a relevant system.**

Keywords-safety;shipbuilding;XML Schema; hazard; risk.

I. INTRODUCTION

The shipbuilding industry refers to ship building and repair sectors. The industry is regarded as one of the most dangerous sectors. Accordingly, safety management is essential task of project management in shipbuilding industry. This promoted consistent efforts for technology advancement concerning shipbuilding processes, facilities and equipment. Still, today most of tasks at shipyards are labor-intensive and requires the specialized, highly skilled. In addition, shipbuilding tasks are mostly performed outdoors, largely influenced by air temperature, climate and other atmospheric environmental factors. Relevant working conditions change constantly. In order to improve safety management, such real workplace environment changes should be reflected in a safety management system promptly. Nonetheless, the current safety management framework is featured by policy aspects covering safety management manuals, safety training for workers and supervision by safety management supervisors. For this reason, proper safety management is not undertaken effectively reflecting actual situations for each worker [1]. In an effort to address this problem, studies are carried out from various technological perspectives. First of all, there is a study striving to improve the current safety management framework by monitoring workers' safety utilizing building information modeling (BIM) [2], virtual reality [3] and augmented reality [4]. Also, there is an endeavor to enhance workplace monitoring technology in terms of worker location monitoring technologies [5]-[8]. Another approach is to improve safety management system in terms of risk analysis-based risk assessment model and related supporting system to prevent accidents [9][10]. While, in terms of safety management logic, it is important that risk factors in each task should be properly identified. This information can be accumulated empirically. Only some processes differ related to what is produced in the same domain. Accordingly, most information with respect to work processes or risk factors can be commonly applicable. But, most of the safety management system is developed upon an assumption that such information is implicitly inherent within the system. In this aspect, we defined XML Schema to ensure that this information is not inherent within the system but explicitly expressed in standardized format XML. By defining work process or risk factor information in XML files based on XML Schema, our approach allows to promptly reflect real-time workplace situations and be made use of by various shipyards or other industrial sites not modifying the logic of safety management systems. The rest of this paper is organized as follows. Several related researches are presented in Section II. Section III presents the XML schema for implementing the safety management system. Section IV presents XML files as examples based on the XML schema. The paper concludes with future work and conclusions in Section V.

II. RELATED RESEARCHES

In the existing approach for developing safety management frameworks, risks are identified through meetings between safety managers and task managers using plans, accident cases and empirical information, etc. These risks do not sufficiently reflect changing situations in real worksites. For these reasons, some visualization techniques, such as BIM, game technologies, virtual reality, and augmented reality have been utilized to improve the current safety management practices. In this respect, there is a study performing 6-day cycle safety plan through 3D modeling of

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the working environment [11]. In addition, there is also an approach offering a framework providing pre-designed virtual project site model in safety management system, for risk identification [12]. Also, there is another approach proposing rule-based safety checking system for falls based on 4D BIM [13]. These researches are a part of visualization technologies for workplace. On the other hand, there are studies about monitoring technologies of real-time locations of workers in workplace. In order to prevent accidents, there is a study using RFID (Radio Frequency IDentification) technologies to track workers' location in real-time [14]. Also, there is an approach that combines wireless communication systems with sensors not using tagging technologies, such as RFID in order to detect moving objects [15]. Its focus is to identify the accurate location of moving workers and objects to prevent accidents. Also, there are studies about risk identification and assessment. Most of risk identification and assessment relies on experiences and expertise of safety management experts or work managers. A study was carried out concerning tools and evaluation models to assist such risk assessment processes [16].

III. XML SCHEMA FOR IMPLEMENTING SAFETY MANAGEMENT SYSTEM

A. *Definition of data relationship for building safety management system*

First of all, we should consider relationship among data that is necessary for building safety management system as shown in Figure 1.

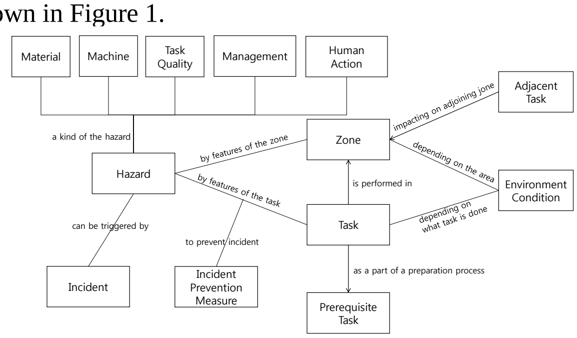

Figure 1. Data relationship for safety management system

As shown in Figure 1, most of accidents at shipbuilding sites are closely related with a task undertaken. Accordingly, a relationship is formed focusing on such task information. As hazard factors exist according to the characteristics of task, task information is related to those factors. As regards prerequisite task like equipment checking carried out before each task may not be considered as individual task but simply as part of a preparation process. Still, since such task can entail hazard factors, a relationship about prerequisite task should also be factored into. Then, each task is performed in a specific zone. This means the features of the zone can influence hazard factors and a relationship is also established with zone information. Furthermore, as climate or other outside environmental conditions can also serve as major hazard factors depending on in which area what task is done, such a relationship should also be taken into account. Especially, in shipbuilding sites, as large-sized objects are handled in a limited space, different processes of work may be performed adjacently in parallel. In this regard, hazard factors of each task can have an impact on adjoining zones, which requires relevant consideration. Hazard factors identified from each perspective can vary ranging from: those related to work materials and equipment; those in an aspect of workplace management; to those from wrong human behaviors. Ultimately, as the goal of safety management system is to prevent accidents, it is required to identify incident factors triggered by each hazard factor, and formulate and define incident prevention measures from the relationship between hazard factors and task.

B. *XML Schema for defining the relationship between Task and Hazard*

It is necessary to define the kinds of specific information required for each information listed in the previous section. It is important to define data structure and relationship in a standardized format utilizing XML formats - a standardized markup language expressing rule sets for data encoding. In this term, the definition rules for specific information - necessary for developing safety management system logic – are defined in XML Schema. Figure 2 illustrates definition of XML Schema for representing task information.

Task ID	Task Code Number	Task Name	Prerequisite Task

```
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
 <xs:element name="tasklist" type="tasklistType"/>
   <xs:complexType name="tasklistType">
      <xs:sequence>
      <xs:element maxOccurs="unbounded" ref="taskitem"/>
      </xs:sequence>
   </xs:complexType>
   <xs:element name="taskitem" type="taskitemType"/>
   <xs:complexType name="taskitemType">
   <xs:sequence>
      <xs:group ref="item" />
      <xs:element maxOccurs="unbounded" minOccurs="0" ref="prerequisitetask" />
   </xs:sequence>
   </xs:complexType>
   <xs:group name="item">
      <xs:sequence>
         <xs:element ref="taskcode" />
         <xs:element ref="taskname" />
      </xs:sequence>
   </xs:group>
   <xs:element name="taskcode" type="taskcodeType" />
   <xs:simpleType name="taskcodeType">
      <xs:restriction base="xs:string">
         <xs:pattern value="[A-Za-z0-9]{3}" />
      </xs:restriction>
   </xs:simpleType>
   <xs:element name="taskname" type="xs:string" />
   <xs:element name="prerequisitetask" type="prerequisitetaskType" />
   <xs:complexType name="prerequisitetaskType">
      <xs:sequence>
      <xs:group ref="item" />
      </xs:sequence>
   </xs:complexType>
</xs:schema>
```

Figure 2. The XML Schema for task information

As shown in Figure 2, in order to express task information, we classified task information into task ID, task code number, task name, and prerequisite task. Task code number is assigned to each task for easy identification in safety management logic. The code number list should be managed in a separate file and adjusted according to individual projects and shipyard situations. Task name represents a textual name for each task. Prerequisite task is a preparatory work performed before main task.

Based on the classification, in order to represent a list of task information, we declared <tasklist> element as the topmost element in the XML Schema. The element <tasklist> contains the <taskitem> element to represent each task as shown in Figure 2. The element <taskitem> comprises the <item> element and the <prerequisitetask> element. The element <item> is used to show the task name and task code number. The <taskcode> element reflects the task code number of each task and shall be supplied in the format of 3 alphanumeric characters. The <prerequisite task> element shall be used to represent the task which should be performed before main task of the <task> element. Since one or more prerequisite tasks shall be existed, we defined the value of ‘maxOccurs’ value as ‘unbounded’. The <prerequisitetask> element shall be represented using the <item> element.

Then, although hazard information is closely related with other information, we defined XML Schema elements for hazards to contain information for the hazard itself to exclude overlap of information. Figure 3 shows the XML schema for representing hazard information.

First of all, we classified hazard information into hazard ID, hazard code number, hazard name, hazard type, causes of incident, and hazard zone.

Hazard code number is assigned to each hazard for easy identification in safety management logic. The code number list should be managed in a separate file and adjusted according to individual projects and shipyard situations. Hazard name represents a textual name for each hazard. Hazard type represents hazard factors identified from each perspective. Causes of incident represent causes of an incident by the hazard. Hazard zone is required for representing the specific zone that can be affected by the hazard.

Based on the classification, in order to represent a list of hazard information, we declared <hazardlist> element as the topmost element in the XML Schema. The element < hazardlist> contains the <hazard> element to represent each hazard as shown in Figure 3. The element <hazard> contains the <hazarditem> element. The <hazard> element contains <hazardcode>, <hazardname>, and <hazardzone>. It also comprises the ‘cause’ attribute and the ‘seriousness’ attribute. The <hazardcode> element reflects the hazard code number of each hazard and shall be supplied in the format of 3 alphanumeric characters. The <hazardname> element reflects the hazard name. In case the hazard occupies the fixed spot, the <hazardzone> element reflects the spot of hazard. The ‘cause’ attribute reflects causes of incident and can be one value of “Falls from height”, "Slips", "Trips", "Hit something fixed/stationary", "Hit by moving/falling object", "Struck by something", and "Collapse".

Next, to represent relationships between a task and hazards, task code number, hazard code number, prevention measures and seriousness can be used. The hazard code number is the hazard which can be occurred by the task. The prevention measures reflect measures that prevent incidents that arise from hazards. The seriousness represents degrees of the seriousness of the incident. Figure 4 shows the XML Schema for representing relationships between a task and hazards information.

Hazard ID	Hazard Code Number	Hazard Name	Hazard Type	Causes of Incident	Hazard Zone

```
<xs:schema xmlns:xs= "http://www.w3.org/2001/XMLSchema">
   <xs:element name= "hazardlist" type= "hazardlistType"/>
   <xs:complexType name= " hazardlistType ">
      <xs:sequence>
         <xs:element maxOccurs= "unbounded" ref= "hazard"/>
      </xs:sequence>
   </xs:complexType>
   <xs:element name= "hazard" type= "hazardType"/>
   <xs:complexType name= "hazardType">
      <xs:sequence>
         <xs:element minOccurs= "1" maxOccurs= "1"  ref= "hazardcode" />
         <xs:element ref= "hazardname" />
         <xs:element ref= "hazardtype" />
         <xs:element minOccurs= "0" ref= "hazardzone" />
      </xs:sequence>
      <xs:attribute ref= "cause"/>
   </xs:complexType>
   <xs:element name= "hazardcode" type= "hazardcodeType" />
   <xs:simpleType name= "hazardcodeType">
      <xs:restriction base= "xs:string">
         <xs:pattern value= "[A-Za-z0-9]{3}" />
      </xs:restriction>
   </xs:simpleType>
   <xs:element name= "hazardname" type= "xs:string" />
   <xs:element name= "hazardtype" type= "hazardtypeType" />
   <xs:simpleType name= "hazardtypeType">
      <xs:restriction base= "xs:string">
         <xs:enumeration value= "Material"/>
         <xs:enumeration value= "Machine"/>
         <xs:enumeration value= "Task Quality"/>
         <xs:enumeration value= "Management"/>
         <xs:enumeration value= "Human action"/>
      </xs:restriction>
   </xs:simpleType>
   <xs:element name= "hazardzone" type= "hazardzoneType" />
   <xs:complexType name= "hazardzoneType">
      <xs:sequence>
         <xs:element ref= "referencepoint" />
         <xs:element ref= "horizontalwidth" />
         <xs:element ref= "verticallength" />
      </xs:sequence>
   </xs:complexType>
   <xs:element name= "referencepoint" type= "referencepointType" />
   <xs:complexType name= "referencepointType">
      <xs:sequence>
         <xs:element name= "x" type= "xs:long" />
         <xs:element name= "y" type= "xs:long" />
         <xs:element name= "z" type= "xs:long" />
      </xs:sequence>
   </xs:complexType>
   <xs:element name= "horizontalwidth" type= "xs:long" />
   <xs:element name= "verticallength" type= "xs:long" />
   <xs:attribute name= "cause" type= "causeType" />
   <xs:simpleType name= "causeType">
      <xs:restriction base= "xs:string">
         <xs:enumeration value= "Falls from height"/>
         <xs:enumeration value= "Slips"/>
         <xs:enumeration value= "Trips"/>
         <xs:enumeration value= "Hit something fixed/stationary"/>
         <xs:enumeration value= "Hit by moving/falling object"/>
         <xs:enumeration value= "Struck by something"/>
         <xs:enumeration value= "Collapse"/>
      </xs:restriction>
   </xs:simpleType>
</xs:schema>
```

Figure 3. The XML Schema for hazard information

TaskHazard ID	Task Code Number	Hazard Code Number	Prevention Measure	Seriousness

```
<xs:schema xmlns:xs= "http://www.w3.org/2001/XMLSchema">
 <xs:element name= "taskhazardlist" type= "taskhazardlistType"/>
 <xs:complexType name= "taskhazardlistType">
   <xs:sequence>
      <xs:element maxOccurs= "unbounded" ref= "taskhazard"/>
   </xs:sequence>
 </xs:complexType>
 <xs:element name= "taskhazard" type= "taskhazardType"/>
   <xs:complexType name= "taskhazardType">
      <xs:sequence>
         <xs:element minOccurs= "1" maxOccurs= "1" ref= "taskcode"/>
         <xs:group minOccurs= "1" maxOccurs= "unbounded" ref= "hazardprevention" />
      </xs:sequence>
      <xs:attribute ref= "seriousness"/>
   </xs:complexType>
   <xs:group name= "hazardprevention">
      <xs:sequence>
         <xs:element ref= "hazardcode"/>
         <xs:element ref= "preventionmeasure"/>
      </xs:sequence>
   </xs:group>
   <xs:element name= "preventionmeasure" type= "preventionmeasureType"/>
   <xs:complexType name= "preventionmeasureType">
      <xs:sequence>
         <xs:element name= "actionitem" type= "xs:string" minOccurs= "1" maxOccurs= "unbounded" />
      </xs:sequence>
   </xs:complexType>
   <xs:attribute name= "seriousness" type= "seriousnessType" />
   <xs:simpleType name= "seriousnessType">
      <xs:restriction base= "xs:positiveInteger">
         <xs:enumeration value= "1"/>
         <xs:enumeration value= "2"/>
         <xs:enumeration value= "3"/>
         <xs:enumeration value= "4"/>
      </xs:restriction>
   </xs:simpleType>
</xs:schema>
```

Figure 4. The XML Schema for relationships between a task and hazards

First, in order to represent a list of mapping information between a task and hazards, we declared <taskhazardlist> element as the topmost element in the XML Schema. The element < taskhazardlist> contains the <taskhazard> element to represent each mapping information as shown in Figure 4. The <taskhazard> element contains the <taskcode> element and the group element <hazardprevention>. The group element <hazardprevention> comprises the <hazardcode> element and the <preventionmeasure> element. The <preventionmeasure> element contains the <actionitem> element that reflects an action item for preventing each hazard. The ‘seriousness’ attribute can be a number from “1” to “4”.

IV. EXAMPLE

This section describes an example that a XML file is defined based on the XML Schema for the safety management system for shipyards.

Figure 5 shows an example of XML representing some tasks of major work processes at shipyards using XML Schema defined in Section III.

Task ID	Task Code Number	Task Name	Prerequisite Task
	000	Marking	Checking NC/M
	001	Primer coating	Checking conveyor
	...	...	...
	010	Checking NC/M	Confirm that use of the NC/M was prohibited
	020	Checking conveyor	Confirm that use of the conveyor was prohibited
	...	....	

```
<tasklist xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="hse_task.xsd">
        <taskitem>
                <taskcode>000</taskcode>
                <taskname>Marking</taskname>
                <prerequisitetask>
                        <taskcode>010</taskcode>
                        <taskname>Checking NC/M</taskname>
                </prerequisitetask>
        </taskitem>
        <taskitem>
                <taskcode>010</taskcode>
                <taskname>Checking NC/M</taskname>
                <prerequisitetask>
                        <taskcode>011</taskcode>
                        <taskname>Stop NC/M</taskname>
                </prerequisitetask>
        </taskitem>
        <taskitem>
                <taskcode>001</taskcode>
                <taskname>Primer coating</taskname>
                <prerequisitetask>
                        <taskcode>020</taskcode>
                        <taskname>Checking conveyor</taskname>
                </prerequisitetask>
        </taskitem>
        <taskitem>
                <taskcode>020</taskcode>
                <taskname>Checking conveyor</taskname>
                <prerequisitetask>
                        <taskcode>021</taskcode>
                        <taskname>Stop conveyor</taskname>
                </prerequisitetask>
        </taskitem>
  .....
  ...

</tasklist>
```

Figure 5. The XML file for task information

It represents XML defined using the <taskitem> element for each task listed in the table in Figure 5.

Figure 6 shows an example of XML representing hazard factors that can be occurred in work processes of shipyards based on the XML Schema defined in Section III.

It represents XML defined using the <hazard> element for each hazard listed in the table in Figure 6.

Hazard ID	Hazard Code Number	Hazard Name	Hazard Type	Causes of Incident	Hazard Zone
	001	NC/M	Machine	Hit by moving/falling object	
	002	Conveyor roll	Machine	Struck by something	
	003	Danger of falling spot	Human action	Falls from height	
	...				

```
<hazardlist xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="hse_in.xsd">
        <hazard cause="Hit by moving/falling object">
                <hazardcode>001</hazardcode>
                <hazardname>NC/M</hazardname>
                <hazardtype>Machine</hazardtype>
        </hazard>
        <hazard cause="Struck by something">
                <hazardcode>002</hazardcode>
                <hazardname>Conveyor roll</hazardname>
                <hazardtype>Machine</hazardtype>
        </hazard>
        <hazard cause="Falls from height">
                <hazardcode>003</hazardcode>
                <hazardname>Danger of falling spot</hazardname>
                <hazardtype>Human action</hazardtype>
        </hazard>
         .....
  ...

</hazardlist>
```

Figure 6. The XML file for hazard information

Figure 7 illustrates an example of XML representing the relationship between tasks and related hazard factors based on the XML Schema defined in Section III.

TaskHazard ID	Task Code Number	Hazard Code Number	Prevention Measure	Seriousness
	010	001	Confirm that use of the NC/M was prohibited	4
	020	002	Confirm that use of the conveyor was prohibited	4

```
<taskhazardlist>
        <taskhazard seriousness="4">
                <taskcode>010</taskcode>
                <hazardcode>001</hazardcode>
                <preventionmeasure>
                        <actionitem>Confirm that use of the NC/M was prohibited</actionitem>
                </preventionmeasure>
        </taskhazard>
        <taskhazard seriousness="4">
                <taskcode>020</taskcode>
                <hazardcode>002</hazardcode>
                <preventionmeasure>
                        <actionitem>Confirm that use of the conveyor was prohibited</actionitem>
                </preventionmeasure>
        </taskhazard>
         .....
  ...
</taskhazardlist>
```

Figure 7. The XML file for relationships between a task and hazards

The first value line of the table in Figure 7 shows the relationship between the task item which has 010 as the ‘Task Code Number’ and the hazard item which has 001 as the ‘Hazard Code Number’. Similarly, the second line of the table in Figure 7 shows the relationship between the task item which has 020 as the ‘Task Code Number’ and the hazard item which has 002 as the ‘Hazard Code Number’.

V. CONCLUSIONS

In order to ensure that the key information, such as task and hazard information for building safety management system is not inherent within the system but explicitly expressed in standardized format XML, we defined XML Schema to express such data in standardized XML formats. Based on it, diverse data of existing systems can be integrated and interoperated in standardized format for the safety management system. In the future, it is essential to conduct studies on how to integrate with a variety of existing systems on the basis of defined XML files. It is also required to develop a framework for the safety management system that can be integrated with existing process management systems.

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