

## Framework for safety-management activity to realize OSHA/PSM

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### Abstract

Process Safety Management (PSM) is a management system that is focused on prevention of, preparedness for, mitigation of, response to, and restoration from catastrophic releases of chemicals or energy from a process plant. Existing PSM such as OSHA/PSM guidelines just indicate the elements, but consistency between elements is not ensured and practical level of elements is different each other. On the other hands, activity model for PSM has been developed to extract the essential activities for maintaining process safety of production plant. In this paper, a general framework of overall PSM is developed based on the activity model for PSM. Proposed framework consists of 'PSM performance in the form of PDCA (Plan-Do-Check-Act) cycle' and 'Resource provision' which can be managed in an integrated fashion. In addition, OSHA/PSM elements have been mapped to clearly specify the position of them within the proposed framework and how each PSM element should function in the PSM.

**Keywords:** Process Safety Management (PSM), Activity Modeling,  
Plant Lifecycle Engineering (Plant-LCE), Plan-Do-Check-Act (PDCA) Cycle

## 1 Introduction

Process Safety Management (PSM) is a management system that is focused on prevention of, preparedness for, mitigation of, response to, and restoration from catastrophic releases of chemicals or energy from a process associated with a facility. OSHA in USA emphasizes PSM and requires the established safety management system as a company as well as the improvement of safety engineering technique <sup>[1]</sup>. OSHA/PSM guideline just indicates 14-elements ((c)-(p)) as shown in Table 1 as it is a performance-oriented standard.

**Table 1 14 elements (c)-(p) required by OSHA/PSM**

(a) Applications	
(b) Definitions	
(c) Employee Participation	(j) Mechanical Integrity
(d) Process Safety Information	(k) Hot Work Permit
(e) Process Hazard Analysis	(l) Management of Change
(f) Operating Procedures	(m) Incident Investigation
(g) Training	(n) Emergency Planning and Response
(h) Contractors	(o) Compliance Audits
(i) Pre-Startup Safety Review	(p) Trade Secrets

In Europe, Seveso II Directive is also a framework of PSM which aims at the prevention of major accidents which involve dangerous substances, and the limitation of their consequences for man and the environment, with a view to ensuring high levels of protection throughout the community in a consistent and effective manner <sup>[2]</sup>. The OHSAS 18001:2007 - Occupational health and safety management systems - requirements is also a PSM system to enable an organization to control its occupational

health and safety risks and improve its performance [3]. AIChE/CCPS (Center for Chemical Process Safety) has published new PSM framework, RBPS (Risk-based Process Safety), which includes nonconventional elements such as process safety culture, measurement and metrics [4].

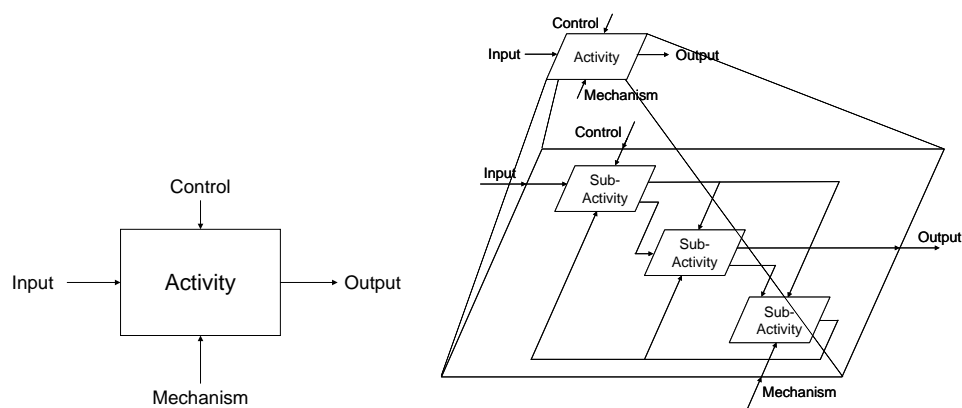
Each PSM system consists of similar elements in broad terms, but consistency between PSM elements is not ensured and practical level of elements is different each other. For these reasons, there are subjects on the position of PSM and the practices such as “how the PSM activity should be executed?”.

In Japan, the importance of PSM based on plant lifecycle engineering (Plant-LCE) for chemical processes, which is from process development to process safety design, plant construction, production, and consistent plant maintenance, has been recognized for several years. This paper proposes a practical framework of overall activity of PSM. Proposed framework consists of ‘PSM performance in the form of PDCA (Plan-Do-Check-Act) cycle’ and ‘Resource provision’ which can be managed in an integrated fashion. In addition, this framework defines the position of PSM elements which reflects the Plant-LCE and the relation between each PSM element.

## 2 Activity Modeling by using IDEF0 Standard

### 2.1 IDEF0 Standard

IDEF0 (Type-zero method of Integrated Definition for Functional model standard) is used as a description format to develop the activity model [5] and is a well-known standardized method for enterprise-resource planning or business-process (re)engineering. Figure 1 shows the basis of activity model using IDEF0 standard. The rectangle represents activity, and the arrows describe information. The information is classified into four categories; i.e. 'Input' to be changed by the activity, 'Control' to constrain the activity, 'Output' to be results of the activity, and 'Mechanism' to be resources for the activity. Each activity can be further developed to sub-activities hierarchically as needed.

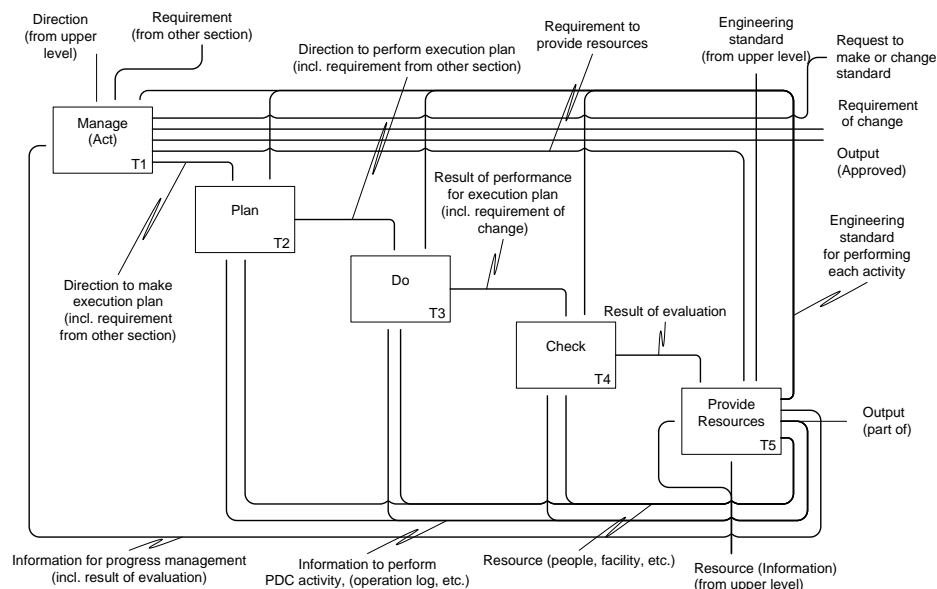


**Figure 1** Basis of activity model using IDEF0 standard

Activity models for process design and plant maintenance have been proposed in a few decades. Aoyama et al. proposed activity models for the process safety design of chemical process plant based on the concept of independent protection layer [6]. Fuchino et al. proposed activity models for performing effective plant maintenance activities and defined the specification of knowledge and information management environment needed to perform each activity [7].

## 2.2 A Template for Activity Modeling

A template has been proposed to generalize the modeling in IDEF0 format and to proceed to a discussion with the goal of integrating each activity model for Plant-LCE [8]. Figure 2 shows the template. This template consists of 'Performance in the form of PDCA cycle' and 'Resource provision'.



**Figure 2** Template for IDEF0 activity modeling

### (1) Performance in the form of PDCA cycle

Basically, each activity should be carried out according to engineering standard (ES; ex. technical standard and control standards) complying with the laws and regulations. 'Manage (Act)' activity manages the progress of overall activities within the same plane, including the requirement of resource provision, improvement of ES, and the decision making of next action for change requirement. The purpose of 'Plan' activity is to make execution plan for given specific directive proportion. 'Do' activity executes plan and gives requirements for administrative defect factors, if any. 'Check' activity evaluates the results and the performance of activities from following viewpoints: a) performance and results for the directive and the plan, b) compliance with ES, c) sufficient provision of resources, and d) validity of ES itself.

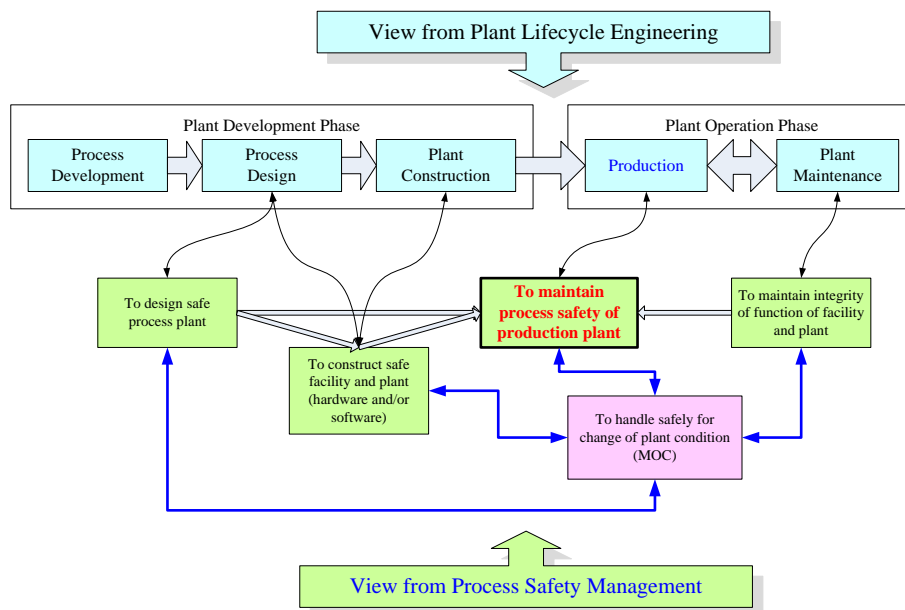
### (2) Resource provision

'Provide Resources' activity provides necessary resources to support and control 'Plan', 'Do', 'Check', and 'Act' activities. These resources include a) educated and trained people and organizations, b) facilities and equipment, tools, and methods for supporting activities, c) information to perform PDC activities, d) information for progress management, and e) ESs for controlling each activity which are distributed from upper level.

Proposed template enables development of activity model to perform activity planning, execution, evaluation and improvement at each breakdown level. That is, activity model based on proposed template shows the implementation in the form of PDCA cycle and the uniform management of ESs with provision of just enough resources. And the model can make the purpose and contents of individual activity clear by adding various information of it. Authors proposed activity model for production management by using this template [9].

### 3 Activity Modeling for PSM

Although the main purpose of PSM is to maintain the process safety of production plant, it could be ensured with the Plant-LCE as shown in Figure 3. Plant development phase means process development, process design and plant construction, and plant operation phase means production and plant maintenance. PSM activity at process design phase is to design safe process plant. PSM activity at plant construction phase is to construct safe facility and plant based on the result of process design. PSM activity at plant maintenance phase is to maintain integrity of function of facility and plant simultaneously with production. Furthermore, it is important to perform PSM activity in the form of PDCA cycle such as planning of safety countermeasure based on the result of risk assessment, execution of plan and evaluation of outputs, to share process safety information through the plant lifecycle, and to make decision to respond to change after ensuring consistency among activities.



**Figure 3 Views from Plant-LCE and PSM**

Based on the template shown in Figure 2, activity model for PSM has been developed to extract the essential activities for maintaining process safety of production plant through the plant lifecycle [8]. Figure 4 shows top activity model for PSM related with Plant-LCE and consists of five activities (A1-A5) which are formed in PDCA cycle; that is management of overall PSM (Manage/Act), planning of PSM (Plan), execution of PSM (Do) and evaluation for performance and result of PSM (Check) and two activities (A6, A7) which have also scheme of uniform management and provision of resources such as human resources and organization (H&O), information, and so on.

Activities A3 and A4 show the execution of PSM (Do) activity based on Plant-LCE. Because the target of PSM is to maintain process safety of production plant, PSM activity through the plant lifecycle can be divided into plant development and plant operation phases in accordance with the classification shown in Figure 3. Purposes of PSM at plant development phase is to develop the safe process plant with established safety measurement and PSM activities related to process development, process design and plant construction are included in this phase. Purposes of PSM at plant operation phases is to maintain the process safety of production plant and PSM activities related

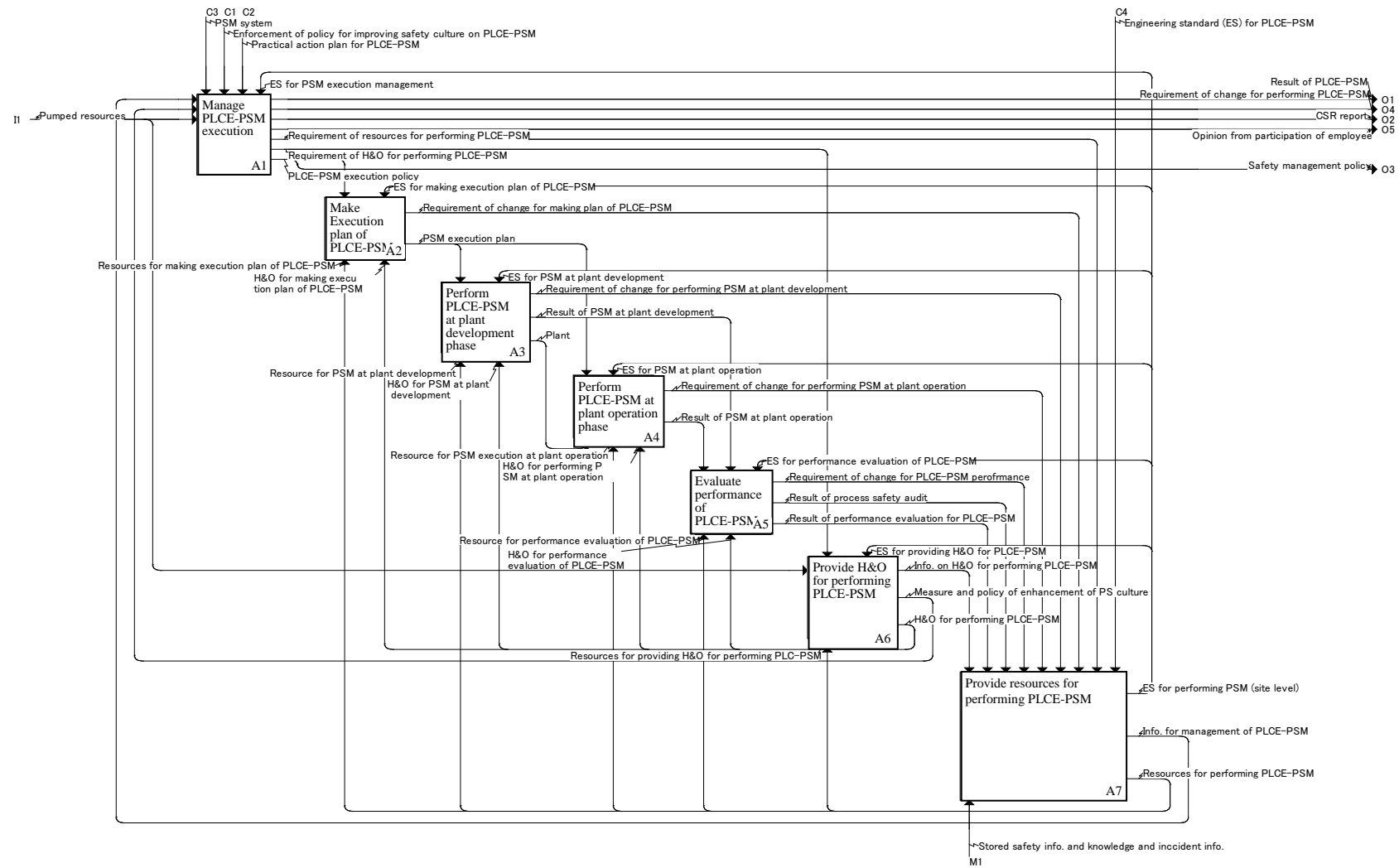
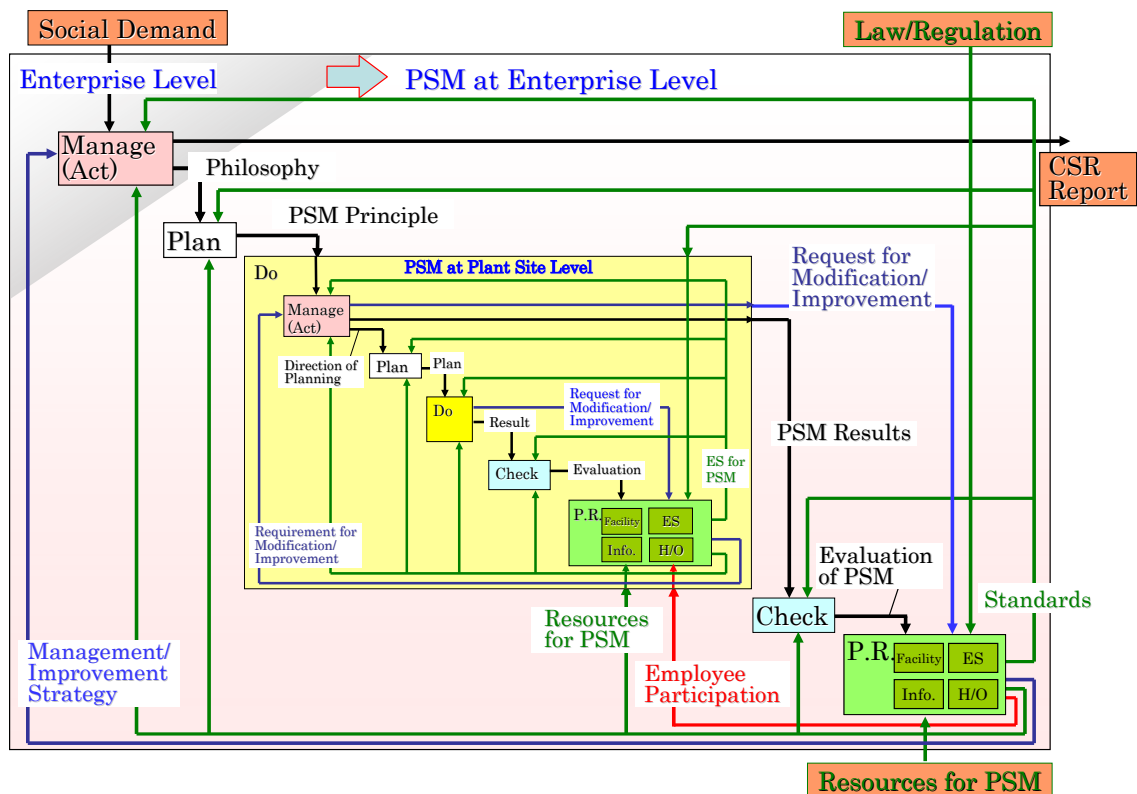


Figure 4 Top activity for PSM with the Plant-LCE

to production and plant maintenance are included in this phase. Outputs from these activities are results of PSM activity, including requirement of change, modification of ESs, and so on. Activities A3 and A4 are further developed to specify the more detailed ‘PDCA’ and ‘Resource provision’ activities for each one in the lower plane.

#### 4 Framework for Overall PSM

As indicated in the activity model for PSM, PSM activity should be performed under company’s management policy and execution strategy and it should be also integrated with engineering activity to ensure safety and stable production through the plant lifecycle. This can be achieved by integration of flow of things and information on production and human and material resources on linked with business management activity. In this paper, a framework for overall PSM is developed by making a summary of activity model for PSM. Figure 5 shows the framework for PSM. This framework has a nested structure which is composed of ‘Performance in the form of PDCA cycle’ and ‘Resource provision’ activities at the enterprise-level and plant-site-level.



**Figure 5 Framework for overall PSM**

##### (1) PSM activities at enterprise-level

As the management system at enterprise-level, it is important to instill philosophy and principle at front-line production site. This philosophy and principle consists of company’s management policy and strategy from the viewpoint of CSR (Corporate Social Responsibility) of top management for “social demand” and “law and regulation”. And, it is necessary to promote employee participation as well as provision of resources on PSM and development of ESs to activate PSM activity at plant-site-level. Then, evaluation for the PSM result and handling activity against request for modification and

improvement from plant-site-level should be performed. The transparency of whole management can be realized by clearly specifying the PSM activity at enterprise-level.

(2) PSM activities at plant-site-level

At the plant-site-level, more concrete PSM activities through the plant lifecycle should be performed for the philosophy and the PSM principle given from management activity at enterprise-level. PSM framework at plant-site-level also has the structure of management system of PDCA cycle and resource provision. Following activities are performed by using resources given from enterprise-level, 1) planning and execution of the plan with Plant-LCE, 2) evaluation for execution results and performances, and 3) information management and requirement for modification and improvement. This ensures to specify the relationships improvement requirement against the defect of plan and so on. The contents and the relationships of provision of resources such as facility, information, human and organization, and ESs needed to perform PSM activity with the Plant-LCE can be specified and steady implementation of PSM activity can be pursued.

### 5 Mapping of PSM Elements on Proposed PSM Framework

In order to make the position of proposed PSM framework for existing PSM system clear, OSHA/PSM elements (Ref. Table 1 for (c)-(p)) have been mapped on it. Figure 6 shows result of mapping. In this instance, the strict definition of OSHA/PSM elements could not be confirmed because of difficulty of interpretation, and rough mapping work has been done.

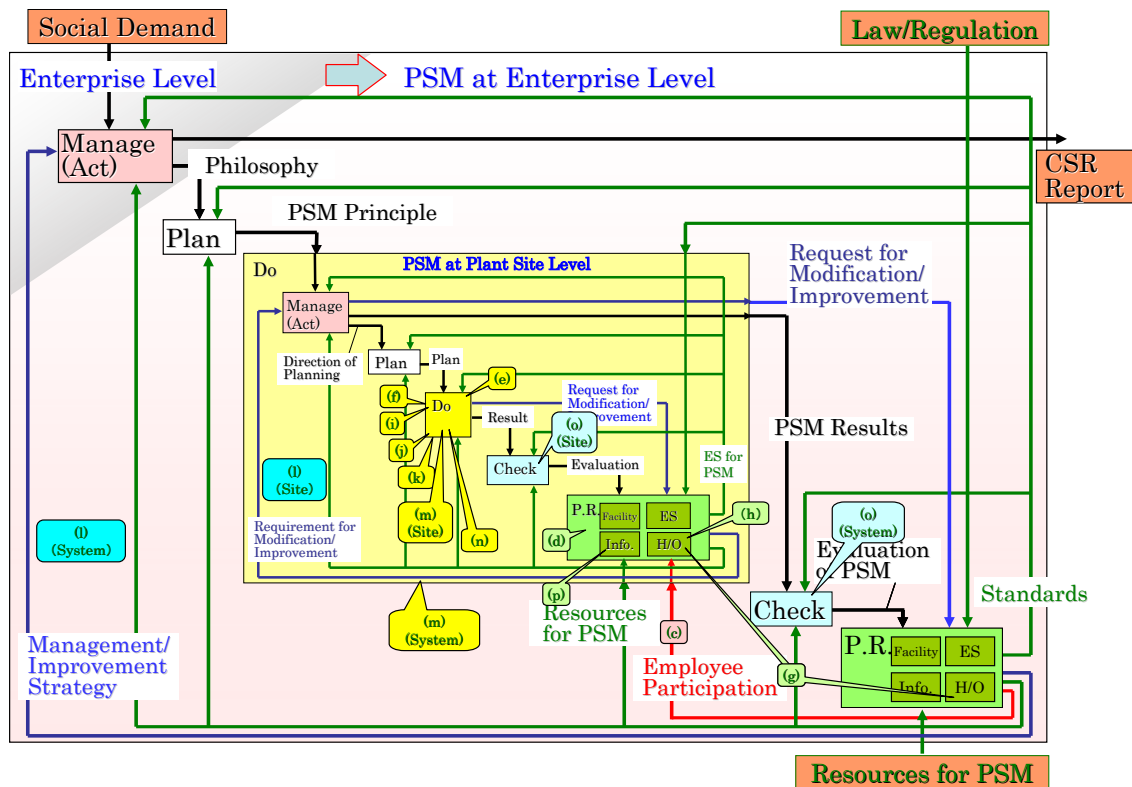


Figure 6 Mapping of OSHA/PSM elements on proposed PSM framework (Ref. Table 1 for (c)-(p))

- “(c) Employee participation” should be considered through the company and is given as resources at enterprise-level.
- “(d) Process safety information” can be managed as a function in ‘Resource provision’ activity and should be provided to each PDCA activities as necessary at plant-site-level.
- “(e) Process hazard analysis” is an important function of ‘Do’ activities at plant-site-level and should be performed through the plant lifecycle.
- “(f) Operating procedures” is prepared at design phase first and should be managed in ‘Resource provision’ activity at plant-site-level so as to make sure that it is up-to-date information.
- “(g) Training” includes on-site and off-site-educations and is activities of providing human resources at plant-site-level and enterprise-level.
- “(h) Contractors” means management of and responsibility for outside organizations at plant-site-level.
- “(i) Pre-startup safety review” is ‘Do’ activity considered at process design phase at plant-site-level.
- “(j) Mechanical integrity” is ‘Do’ activity performed at plant maintenance phase at plant-site-level.
- “(k) Hot work permit” is ‘Do’ activity prior to beginning the hot work operation at plant-site-level.
- “(l) Management of change” which is recognized as the most important element of PSM, should be functioned as structures of PDCA cycle at plant-site-level and enterprise-level mutually.
- “(m) Incident investigation” is ‘Do’ activity following the incident and should be performed from not only safety technical view at plant-site-level but also management one at enterprise-level.
- “(n) Emergency planning and response” is ‘Do’ activity considered at process design and implemented in the emergency situation at plant-site-level.
- “(o) Compliance audits” is ‘Check’ activity and is divided into the evaluation of PSM activity at plant-site-level and the audit for PSM system at enterprise-level.
- “(p) Trade secrets” is regarded as ‘Resource provision’ activity because the purpose of it is to provide information on PSM to all PSM concerned.

As shown in Figure 6, the position of each PSM elements and relationships between them can be clearly specified in the framework which has structure of ‘Performance in the form of PDCA cycle’ and ‘Resource provision’. This means proposed PSM framework is not fully new system but comprises of existing PSM systems. The detail position of PSM activity for usual Plant-LCE activities can be also made clear in the PSM framework. Eventually the company can revitalize PSM activity.

## 6 Discussion and Conclusion

This paper proposes a practical framework for PSM based on Plant-LCE. This is developed based on activity model for PSM by using IDEF0 format. OSHA/PSM elements have been mapped on the proposed PSM framework. Proposed PSM framework provides following advantages.

- (1) Proposed PSM framework can be useful for various chemical process companies because it has been developed based on function-based discussion by using IDEF0 format.



- (2) To clarify that target of PSM is the safety management of production plant makes the purposes of process development, process design, plant construction and plant maintenance works and the positions of PSM elements with the Plant-LCE clear.
- (3) By using a template to specify management system in the form of PDCA cycle, even if some problems happen in the result and performance of PSM activity, they will be corrected by 'Check' and 'Act' activities (ex. change requirement). Because 'Check' activity evaluates not only the result of performing activity at plant-site-level but also the PSM framework itself at enterprise-level, the performance as PSM system can be also improved progressively in the form of PDCA cycle.
- (4) Resources required for performing the PSM activities can be clearly specified. Provision of human resources and organization is represented as an activity. This activity can clarify the positions of education and training, contractor management, etc. which are parts of elements of PSM system. Another provision of resources such as information, tools, methods, etc. is also represented as an activity. This makes it possible to define the structure of PSM information sharing through the Plant-LCE.
- (5) Environment which integrates PSM activity with production activity is developed.
- (6) Position of elements of OSHA/PSM can be clarified. This means proposed PSM framework is not entirely-new system but is comprises of existing PSM systems.

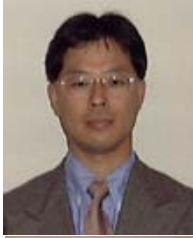
## 7 References

- [1] OSHA, 29CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals (1992)
- [2] Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances (1996)
- [3] OHSAS 18001 Health & Safety Standard, <http://www.ohsas-18001-occupational-health-and-safety.com/>
- [4] AIChE/CCPS, Guidelines for Risk Based Process Safety, WILEY (2007)
- [5] IDEF0 Overviews, <http://www.idef.com./idef0.html>
- [6] Aoyama,A., et.al., A Framework of Independent Protection Layer Design for Process Industries, 6th International Conference on Probabilistic Safety Assessment and Management, PSAM6, 9G (2002)
- [7] Fuchino,T., et.al., Business Process Model for Knowledge Management in Plant Maintenance: 18th European Symposium on Computer-Aided Process Engineering, Elsevier, pp.955-960 (2008)
- [8] Shimada,Y., et al., Practical Framework for Process Safety Management based on Plant Lifecycle Engineering, 3rd International Conference on Integrity, Reliability & Failures, S1707\_A0531 (2009)
- [9] Shimada,Y., et.al., Reference Model for Safety Conscious Production Management in Chemical Processes, 13th International Symposium on Loss Prevention and Safety Promotion in the Process Industries, Vol.1, pp.629-632 (2010)

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