An Integrated Management for Occupational Safety and Health throughout the Plant-Lifecycle

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Abstract: The main purposes of occupational safety and health (OSH) management are to assure safe and healthful working conditions for working men and women and to prevent industrial accidents by the establishment of process safety management (PSM) system in the company level as well as the improvement of safety engineering techniques. Business process model has been developed to systematize the engineering activities and information flow throughout a plant-lifecycle (i.e. from research and development through process/plant design, construction and active manufacturing period, including production and maintenance) of chemical processes. This paper proposes an integrated approach for OSH management based on the business process model of engineering activities. This approach consists of three level hierarchical PSM; 1) PSM framework at enterprise-level, 2) HSE (Occupational Health, Process Safety, and Work Environment Protection) management activities at middle-management-level, and 3) SQDC-conscious tasks at manufacturing-site-level. Hierarchical integration of the PSM at each level makes it possible to realize the consistent and collaborative OSH management.

Keywords: Occupational Safety and Health Management, Process Safety Management System, Business Process Model, HSE Management, SQDC (Safety, Quality, Delivery, Cost)

1. INTRODUCTION

There has been a recent surge in the number of disasters and incidents in occurring in the process industry (e.g. the petrochemical, chemical, food and pharmaceutical industries). The reasons include defects in process-safety management (PSM); inadequate safety management systems in companies; inadequate knowledge among managers and insufficient information about the tasks undertaken and resultant erroneous operation and/or misjudgment; no standardization for the PSM activity; and other engineering factors. Expecting that PSM will reduce the hazards and likelihood of disasters, OSHA in USA emphasizes PSM and requires that companies establish PSM systems and improve safety engineering techniques[1]. Existing PSM guidelines, OSHA/PSM, Seveso II Directive[2], OHSAS180001[3], and others, establish only minimum elements for safety management. The Ministry of Labor, Health and Welfare of Japan released "Guidelines on Occupational Safety and Health Management Systems" in 1999 (amendment, 2006)[4]. Purposes of occupational safety and health (OSH) management are to assure safe and healthful working conditions for workers and to prevent industrial accidents by the improvement of each company's PSM system as well as safety engineering techniques.

This paper proposes an integrated approach for OSH management based on business process model of engineering activities. Hierarchical PSM consist of PSM framework at enterprise-level, HSE (Occupational Health, Process Safety, and Work Environment Protection) management activities at middle-management-level, and SQDC (HSE, Quality, Delivery, and Cost)-conscious tasks at manufacturing-site-level. Hierarchical integration of the PSM makes it possible to realize the consistent and collaborative OSH management.

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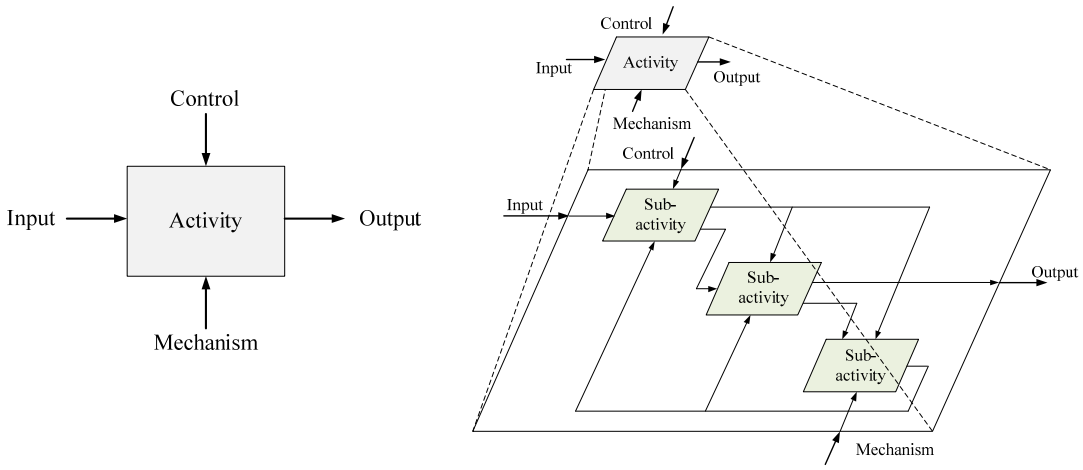
2. BUSINESS PROCESS MODEL FOR THE PLANT-LIFECYCLE ENGINEERING

2.1 Basis of Business Process Model

In order to achieve a systematic PSM, a model-based engineering framework is needed so that information can be used to inform all stages of the plant-lifecycle (i.e. from research and development through process/plant design, construction and active manufacturing period, including production and maintenance). Constantly updated and revised data and information must be shared at each engineering stage in a transparent way in order to examine the impacts of safety decisions of all activities of the chemical process plant.

Among the challenges by the safety division of the Society of Chemical Engineer Japan, IDEF0 (Integrated DEfinition for Functional model standard, Type-zero)[5] is adopted as a description format to develop the business process model. IDEF0 is a well-known standardized method for enterprise-resource planning or business-process (re)engineering. Figure 1 shows the basis of the IDEF0 format. The rectangle represents an 'activity (function)', and the arrows describe information. The information is classified into four categories: 'Input' which is changed by the activity, 'Control' which constrains the activity, 'Output' which is the result of the activity, and 'Mechanism' which includes the resources of the activity. The information is collectively termed ICOM (Input, Control, Output, and Mechanism). Each activity can be further developed hierarchically to detail sub-activities as needed. Development of a business process model using the IDEF0 format enables function-based discussions.

Figure 1 Basis of IDEF0 Format



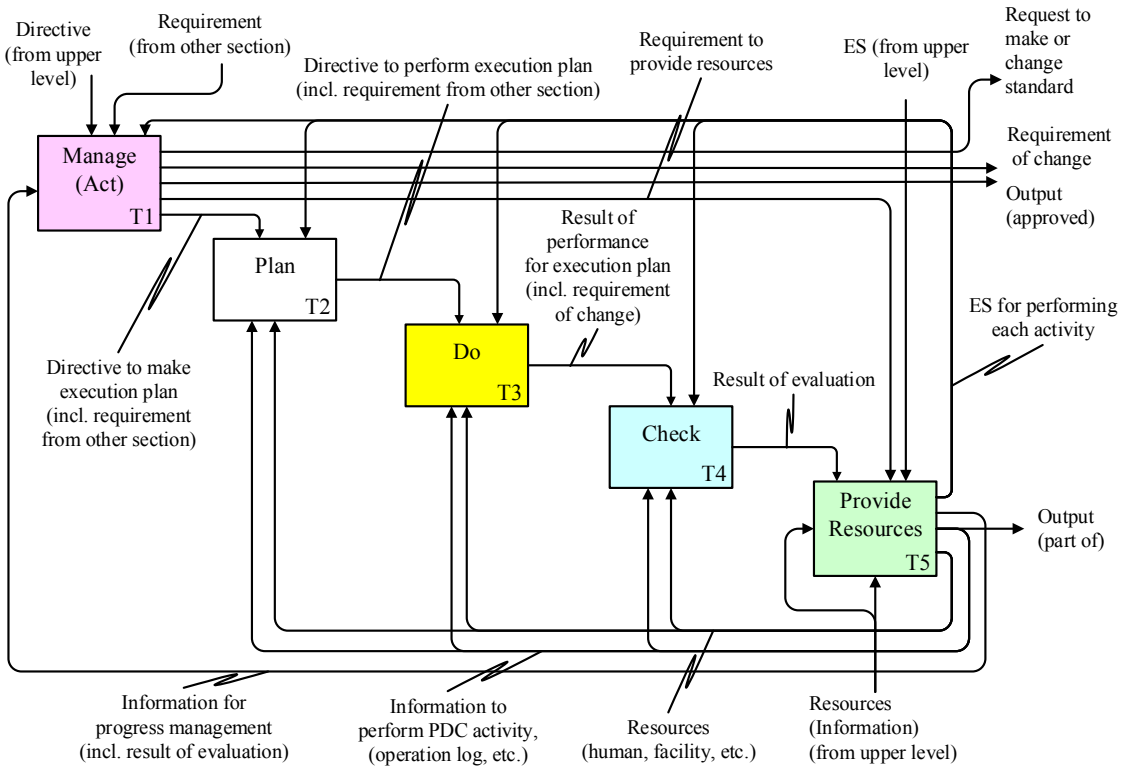
2.2 Template for Business Process Modelling

The PIEBASE (Process Industry Executive for achieving Business Advantage using Standards for data Exchange) was an international consortium to achieve a common strategy and vision for the delivery and use of internationally accepted standards for information sharing and exchange (ISO-STEP), and developed a business process model to represent the core business activity of the chemical process industry[6]. The PIEBASE model uses a template approach across all principal activities. This template consists of three steps: (1) manage, (2) do, and (3) provide resources. The purpose of the PIEBASE model is to provide a common understanding of the engineering and information requirements of processes throughout the plant-lifecycle. However, the activities in the model were defined to reflect current practices.

On the other hands, as shown in Figure 2, a template for business process modelling (BPM-template) of plant-lifecycle engineering (Plant-LCE) has been proposed to generalize the modelling in IDEF0

format and enable discussion of integrating each business process model for Plant-LCE[7]. This BPM-template consists of two functions: "Performance in the form of a PDCA-cycle[8]" and "Resource provision".

Figure 2: BPM-template for Business Process Modelling



(1) Performance in the form of PDCA-cycle: Each activity should be carried out according to engineering standards (or ESs; e.g., technical standards and control standards) complying with laws and regulations.

- The 'Manage' activity manages the progress of overall activities within the same plane, including the requirement of resource provision, the improvement of engineering standard, and the decision making of the next action for change requirement.
- The purpose of the 'Plan' activity is to make an executable plan for a given specific directive.
- The 'Do' activity executes a plan and yields requirements for administrative defect factors, if any.
- The 'Check' activity evaluates the results and the performance of the previous activities to support these goals: a) performance and results for the directive and the plan, b) compliance with engineering standard, c) sufficient provision of resources, and d) validity of the engineering standard itself.

(2) Resource provision: 'Provide Resources' activity provides the 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 and for progress management; and d) engineering standards for controlling each activity, which are given from the activity of the upper plane.

This BPM-template enables the development of a business process model to perform activity planning, execution, evaluation, and improvement at each sub-activity plane. That is, the model based on the proposed BPM-template shows implementation in the form of the PDCA-cycle and the uniform management of engineering standards with the provision of just enough resources. Furthermore, the developed model can clarify the purpose, the contents, and the relevant ICOM of individual activity and provide a framework of logical PSM.

2.3 Business Process Model for Plant-LCE

Business process model should be seen as a 'to-be' model that represents the logical business process. The following points are required for a referenceable model.

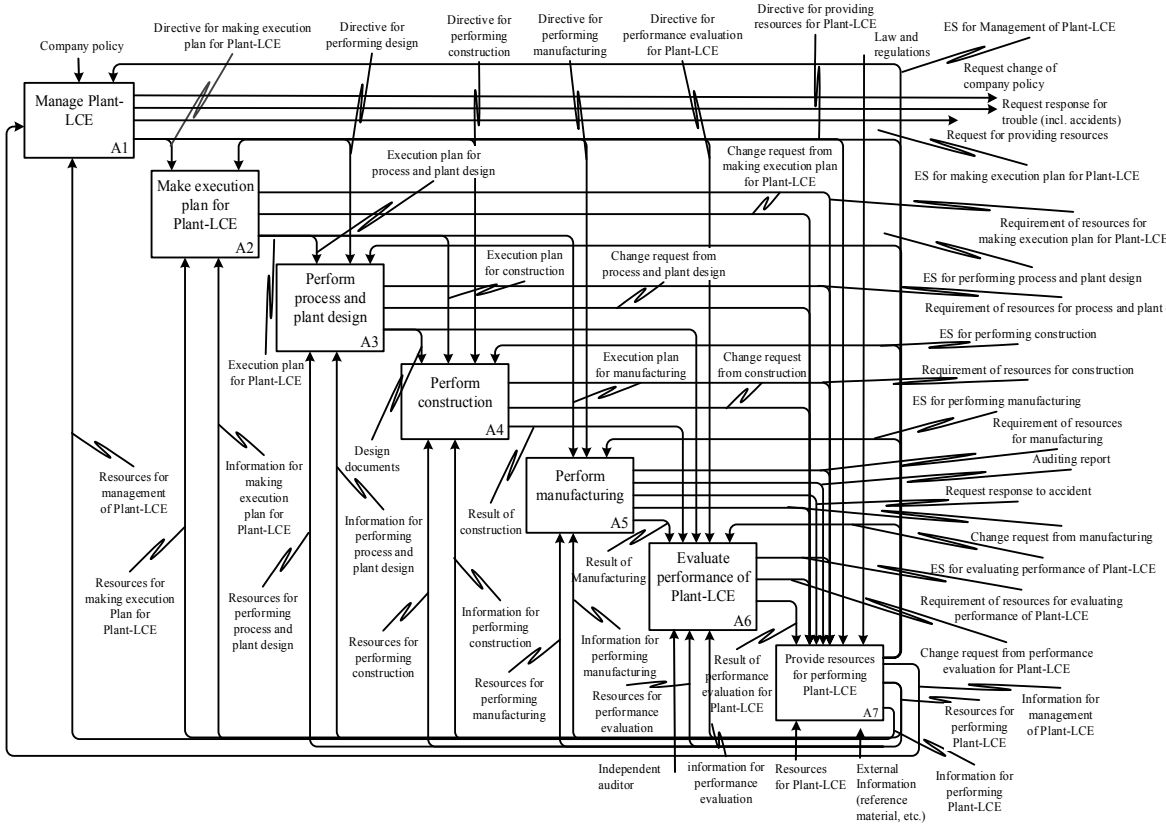
- The definitions of business functions and the scope of them must be clarified before starting the development of a model.
- Activities that develop technologies and activities that use technologies for engineering functions should be clearly distinguished.
- Activities must be categorized as 'Plan', 'Do', 'Check (Evaluate)', or 'Manage (Act)' activities in order to develop a model that constitutes an activity framework in the form of a PDCA-cycle.

Furthermore, two points must be kept in mind so as not to create a business process model that only represents a specific company's activities.

- The model should be considered separately from the company by assigning tasks based upon on organizational structure not specific workers in the specific company. That is, tasks should not be based on the question of "who should do them?", but rather on "what has to be done?"
- Specific activities in an individual company should not be the focus of the model. Widely-used and generalized structures of activities and information flow related to the activities should be developed.

Activities that are performed at actual companies (plant engineering companies, plant operation companies, etc.) have been compiled and examined, and business process models have been developed based on the BPM-template. Figure 3 shows a business process model reflecting the activities of Plant-LCE. 'Do' activities of this model are comprised of activities of process and plant design, construction, and manufacturing (production and maintenance) stages[9].

Figure 3: Business Process Model Reflecting the Activities of Plant-LCE



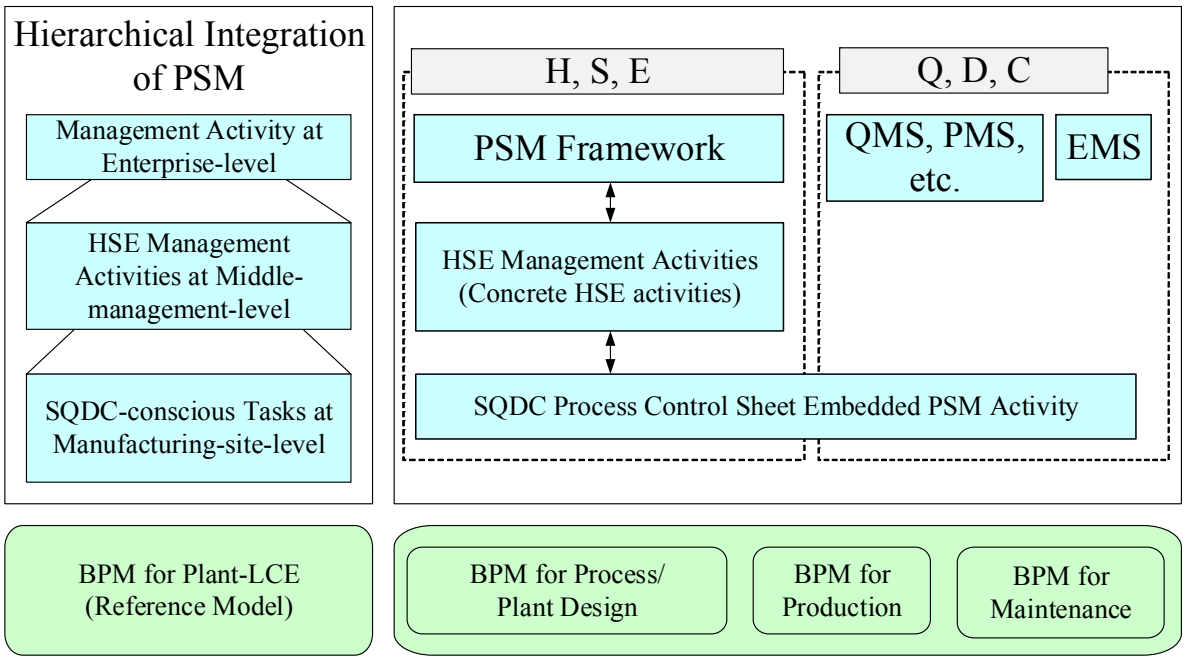
The developed business process models systematically show the universal activities and information flow at each engineering stage. These models can clarify the business process in the form of the PDCA-cycle throughout the plant-lifecycle as well as at each engineering stage, and the resource provision to share the process-safety information, to ensure consistency of engineering standards, etc. A logical and consistent business flow for each company can be developed by referring to these models. A specific business flow shows the framework, activities, information, etc. that are needed in order to prevent malfunctions and accidents, and is useful for the development of an environment for a systematic PSM.

3. INTEGRATED APPROACH FOR OCCUPATIONAL SAFETY AND HEALTH (OSH) MANAGEMENT

3.1. Hierarchical PSM

Systematized PSM can be established based on the essential requirements of the PSM activity, that are management, planning, execution, evaluation, and improvement (PDCA-cycle) and the resource provision. These are embedded clearly in the business process model of engineering activities. This paper proposes an integrated approach for OSH management based on the business process model of engineering activities. Figure 4 shows the structure of hierarchical integration of the PSM. PSMs at enterprise-level, middle-management-level, and manufacturing-site-level are systematized respectively to realize the consistent and collaborative OSH management.

Figure 4: Structure of Hierarchical Integration of the PSM



QMS: Quality Management System, PMS: Production Management System,
EMS: Environment Management System, BPM: Business Process Model

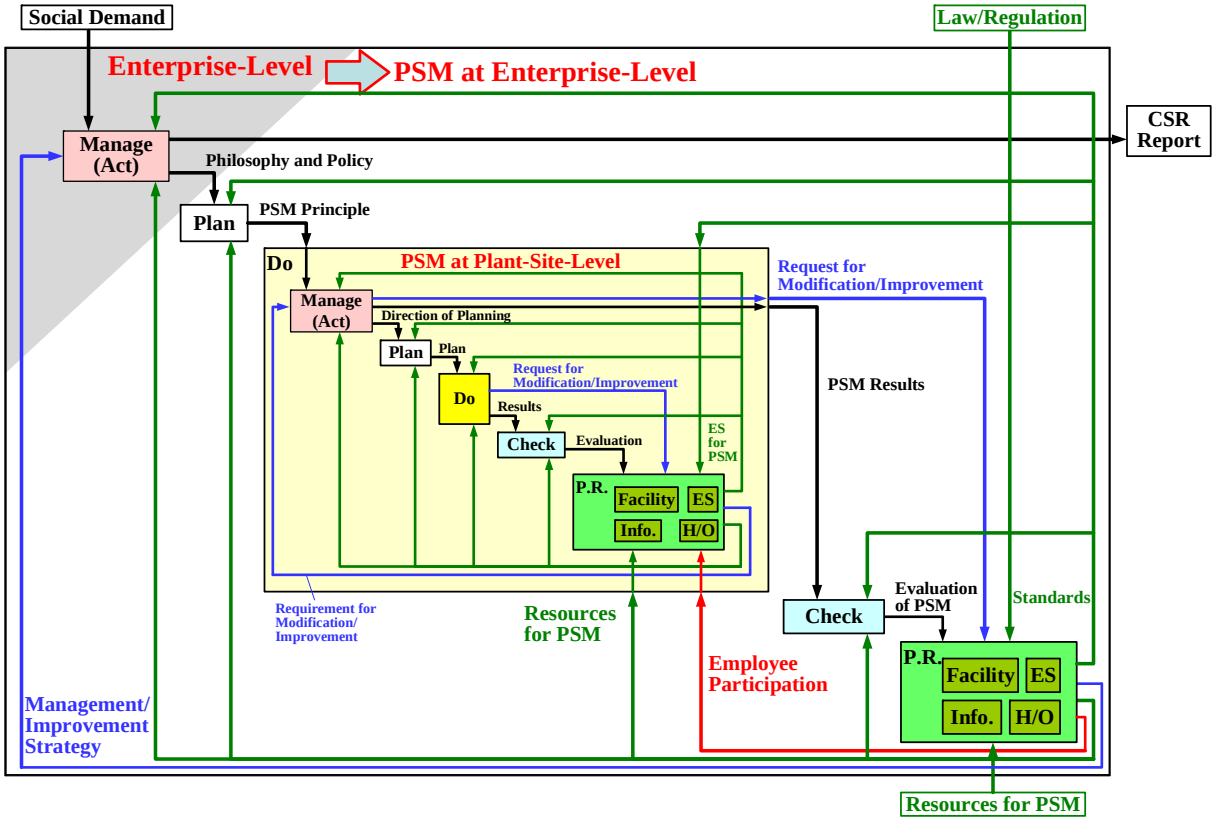
3.2. PSM Framework at Enterprise-Level

Shimada et al. has developed business process model for PSM by extracting the essential activities and the information for maintaining the process safety based on the business process model of the engineering activities[10]. For the PSM strategy reflecting corporate philosophy and policy for the social demand, OSH management system is created so as to clarify the implementation of PSM

activities in the form of PDCA-cycle and the provision of resources (human resources, facilities and equipments, information, etc.) needed to accomplish the activities.
Business process model for PSM has been summarized by embedded structure of PDCA-cycle at enterprise-level and plant-site-level respectively and a comprehensive PSM framework has been structured based on the model as shown in Figure 5. It has been confirmed that the position of the PSM functions (e.g. 14 elements in OSHA/PSM) can be defined as the concrete engineering activities throughout the plant-lifecycle[10]. This confirmation makes it possible to specify how each PSM element should function in the usual engineering activities. Proposed PSM framework can be applied to improvement of company-specific PSM system to match a business's configuration. Features of proposed PSM framework are follows.

- Relation of PSM activities between enterprise-level and plant-site-level can be clearly specified.
- Improvement requirement against the defect factor on the result of implementing the PSM activities can be clarified as management system in the form of PDCA-cycle.

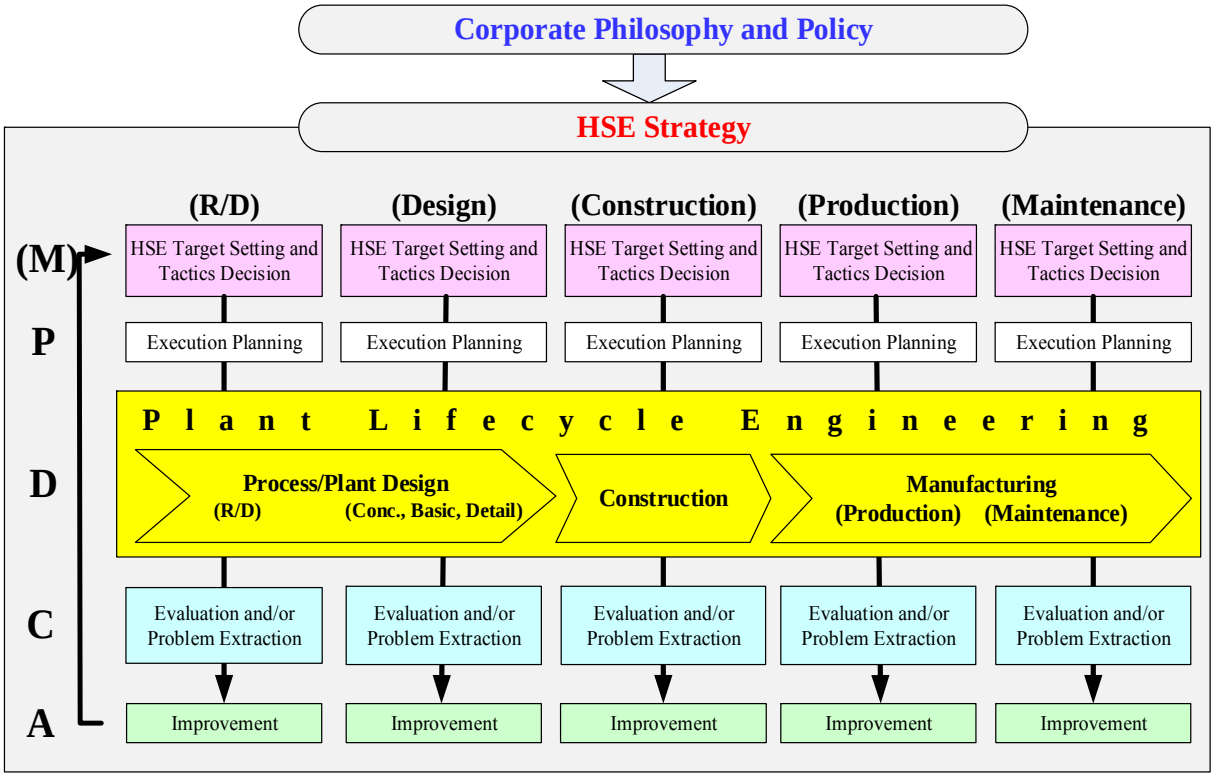
Figure 5: Framework for Overall PSM Activities



3.3. HSE Management Activities at Middle-Management-Level

In this paper, not only process safety but also occupational health and work environment protection are considered as HSE management activities at middle-management-level. HSE management activities have been systematized to embody PSM activities at middle-management-level under the PSM framework[11,12]. Figure 6 shows systematized HSE management throughout the plant-lifecycle. For each engineering stage, HSE manager demonstrates the HSE target setting and tactics decision according to the HSE strategy presented from the enterprise-level. HSE management activities should be also improved in the form of PDCA-cycle, that is formulating the HSE execution plan for the HSE target and tactics, implementing the plan, evaluating the implementation of the plan, and improving where necessary, with provision of just enough resources to perform each activity. Each HSE management activities are adapted in the form of PDCA-cycle with resource provision.

Figure 6: HSE Management Activities throughout the Plant-LCE



Concrete HSE management activities and related HSE resources at each engineering stage of plant-lifecycle have been analyzed and listed for the systematized HSE management. Table 1 shows a part of list of the HSE management activities at production stage. 'Do' activities are classified according to H/S/E categories, that is occupational health, process safety, and work environment protection. Table 2 shows a part of list of the resources for HSE management activities at production stage. HSE resources are clarified into people and organization, facilities and equipments, information, and HSE standards. HSE resources needed for performing Plan-Do-Check-Act activities are listed in the columns of Input, Control and Mechanism. HSE resources which should be provided by performing "HSE provide resource" activity are listed in the column of Output.

HSE manager can review the HSE management activities which should be performed currently by referring the systematized HSE management and the list of concrete HSE management activities. It can lead to implement the company-oriented and 'to-be' PSM system.

3.4. SQDC-Conscious Tasks at Manufacturing-Site-Level

A method of production management using SQDC process control sheet[12] is proposed as one of the PSM activities at manufacturing-site-level. SQDC process control sheet is developed by the addition of the viewpoints of SQDC for the production with respect to existing QC (Quality Control) process chart which has been used to maintain and improve the quality of products in the manufacturing. In this sheet, engineering standards such as standard operating procedure (SOP), rules are associated with each process as reference information to perform the HSE management activities. Figure 7 shows an example of SQDC process control sheet. A sheet is used for summarizing the process briefly to stimulate the PSM activities at the manufacturing-site. SQDC process control sheet helps field workers execute daily production tasks to prevent any possible troubles and/or industrial accidents as well as improve the quality and the productivity of the product at manufacturing-site. Field manager can also control their sure task executions for PSM according to this sheet.

Table 1: A Part of List of HSE Management Activities at Production Stage

	Activity	Contents
Plan	Execution Planning	►Formulation of HSE execution plan - HSE execution plan for HSE targets and tactics at production stage
Do	Engineering for Occupational Health	►Investigation of related laws and regulations - Related laws and regulations with occupational health
	Engineering for Process Safety	►Investigation of related laws and regulations - Related laws and regulations with process safety - Hazard data of materials, MSDS, etc. ►Hazard identification - Operational risk, hazard data of process and materials, MSDS, etc. ►Safety countermeasure for safety operation - Confirmation access for operation - Takeover operational information - Monitoring safety under operation - Maintenance request for equipment trouble ►Documentation for safety operation management - Education document on operation history - Information of accident or trouble ►Education and training for safety operation management - Education and training for safety routine or non-routine operation on education plan
	Engineering for Work Environment Protection	►Investigation of related laws and regulations - Related laws and regulations with work environment protection
Check	Evaluation and/or Problem Extraction	►Evaluation of implementation of HSE execution plan - Check points for compliance with laws and regulations - Evaluation points for HSE activities performance at production
Act	Improvement	►Improvement, where necessary - Review for audit results, defected factors of production, etc. - Modification of HSE targets and tactics of production, etc.

Table 2: A Part of List of Resources for HSE Management Activities at Production Stage

	Category	Input, Control, Mechanism	Output
HSE Resources	People and Organization	- License for related laws and regulations - Document for HSE education and training - Equipment for HSE education and training	- Results of medical check - Results of mental health care - Results of education and training
	Facilities and Equipments	- Fire control or fire-fighting equipment, etc. - Block & blowdown facility, Safety valve, etc. - Drafter, Emergency power source, etc.	*Same as on the left*
	Information	- Hazard data and SDS - Design base information - Construction plan under operation - Maintenance plan and result - Responsible care support data	- Plant operation data (SQEA monitoring data) - Results of hazard identification on HSE - Incident or trouble reports - Equipment trouble reports
	HSE Standard	- HSE department tactics and HSE plan - Applied laws and regulations - Standard for safety operation, MOC, emergency response, etc. - Plan of education and training	*Same as on the left*

Figure 7: An Example of SQDC Process Control Sheet

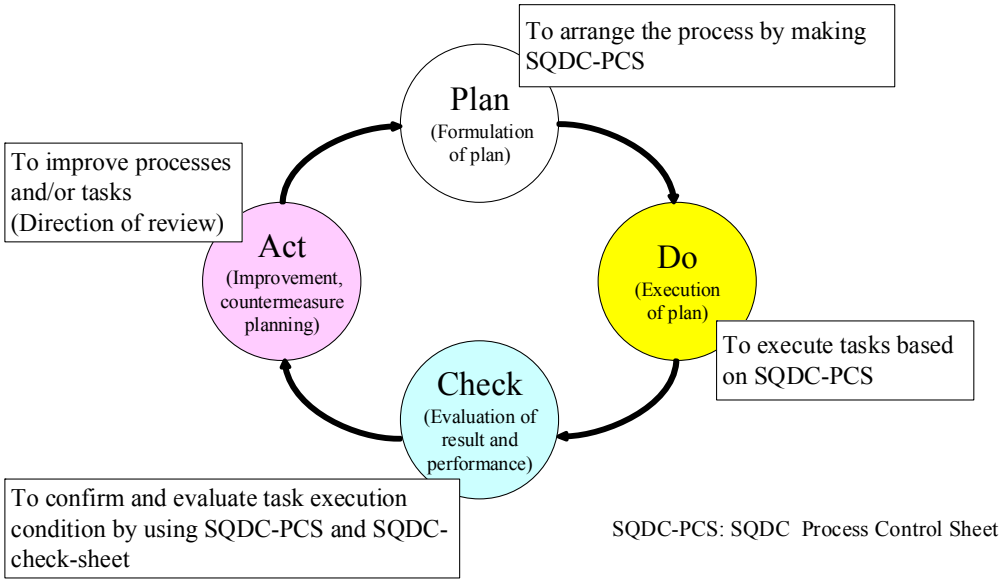
Name	DOP					Authorization	Audit	Development

Symb.	○ Process	◇ Inspection		Version 1	2013-03-18	AA
	○ Transport	▽ Holding	Pub. No.	Revision 1	2013-04-19	BB
				Revision 2	2013-05-19	BB

Process				Managerial feature (SQDC)				Management guide			Standard	Precaution
Process flow diagram												Claim
R.M.	Sub-process	Main process	Process name	Equip./ Fac.No.	Managerial item	Control point	Freq.	Remark (Ref. info.)	Worker	Management method and record sheet	Manager	Operation standard (Work standard)	Operation (process) trouble Occupational accident
			0) Planning & scheduling										
					Quantity, Delivery time, Order, Basic unit		Every order		Planing Sec.	Production plan and schedule	Planing Sec. Chief	Production planning and scheduling rule	
		1 Raw material	1) Raw material acceptance										
			Acceptance	T-001 ～T-012	Product (Quantity, Lot) **Leak**	RM accept. control standard, **Safety standard**	Every accept.	Check gas-detector	Procure. Sec.	R.M. management sheet	Procure. Sec. Chief	Acceptance rule	
		2 Reaction preparation	2) Reaction preparation	R-101									
			Tank check	T-001, T-002	Product (Quantity (level))	> Lower storage level limit	Every batch		Production Sec. (A group)	Reaction record sheet	Production Sec. Chief	Storage rule	
			Line-up	T-007, T-012	Line setting	Valve check list		Technical standard, P&ID, etc.					
			N2 substitution		N2 Press., O2 conc., Leak	1 bar (3 times), O2=N/D						SOP	
		3 Feed	3) Raw material Feed	R-101									
			Fresh 2EH Feed	<- T-001	F2EH (Quantity, Rate)	1 ton: 4m3/hr	Every batch	**Emergency response standard, Technical standard**	Production Sec. (A group)	Reaction record sheet	ditto	SOP	**Abnormal reaction**
			Agitation		Agitation rate	Mode: MILD (35 < rpm < 45)							**Local heating**
			Steam heating		Steam temp.	145 C < T < 155 C							**Leak and ignition due to overload press. to elimination equip. (Abnormal press.)**
		4 Reaction 1	4) 1st esterificatin reaction	R-101	Reaction temp. Reaction time	150 C 5 hr							
			FAU Feed	<- T-002	FAU (Quantity, Rate)	Stop agitation at feeding 1.5 ton: 9m3/hr	Every batch	Emergency response standard,	Production Sec. (A group)	Reaction record sheet	ditto	SOP	**Leak and ignition due to overload press. to elimination equip. (Abnormal press.)**
			:	:		:	:	:	:	:	:	:	:
			:	:		:	:	:	:	:	:	:	:

Figure 8 shows a PDCA-cycle of SQDC-conscious tasks execution using SQDC process control sheet. SQDC process control sheet is developed for process arrangement (Plan). SQDC-conscious tasks are implemented using the SQDC process control sheet (Do). Results of implementation are evaluated using the SQDC process control sheet and the SQDC-check-sheet, which is developed separately (Check). For the evaluation results, process, activities and engineering standard such as work instructions are reviewed and improved (Act). This PDCA-cycle activity leads to improvement of PSM at manufacturing-site-level.

Figure 8: A PDCA-cycle of SQDC-conscious Tasks using SQDC Process Control Sheet



Following positive effects are expected for implementing the SQDC-conscious tasks using the SQDC process control sheet.

- Field workers are not required to perform new and additional tasks, but required to implement steadily the SQDC managerial features written in the SQDC process control sheet. This becomes possible to perform each process without omission and duplicate works for viewpoints of safety as well as quality and productivity. It can lead to cost reduction.
- Field workers can execute their tasks confirming and understanding not only how they can do it (know-how) but also why they should do it (know-why).
- To ensure the consistency of manual, SOP, etc. written in 'Standard' section and to provide them as resources for implementation of each process facilitate the improvement of processes and tasks at manufacturing-site-level and the prevention of the variability of the tasks between field workers, mismanagement, error of check, etc.
- Field manager can manage the production which satisfies the requirements for OSH management.

4. CONCLUSION

This paper proposes an integrated approach for OSH management based on the business process model of engineering activities. PSMs at enterprise-level, middle-management-level, and manufacturing-site-level are integrated in a hierarchical way. The approach is based on formulating the execution plan for specified objectives (Plan), implementing the activities as planned in compliance with engineering standard (Do), and evaluating the result of implementation of activities (Check). If some defect factors happen, countermeasures are considered and improved at next activities and tasks (Act). Furthermore, each activity of 'Plan', 'Do', 'Check', and 'Act' can be performed steadily by providing the resources (human resources, facilities and equipments, information, etc.) needed to perform each activity and complying with the engineering standards.

Proposed hierarchical integration of the PSM does not treat the PSM activities as special and additional tasks, but views the consistency, the affinity, the accommodativeness with production activities as the basis of PSM activity. PSM activities at each level make it possible to realize the consistent and collaborative OSH management.

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