Designing Continuous Safety Improvement within Chemical Industrial Area.

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Designing Continuous Safety Improvement within Chemical Industrial Areas

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Abstract

This article provides support in organizing and implementing novel concepts for enhancing safety on a cluster level of chemical plants. The paper elaborates the requirements for integrating safety management systems of chemical plants situated within a so-called chemical cluster. Recommendations of existing Plant Safety Management System Codes of Good Practice are analyzed in relation to the needs of cluster chemical safety. The paper establishes comprehensive guidelines for gradually standardizing Plant Safety Management Systems through the design, the development and the installation of a Cluster Safety Management System within a group of chemical companies. A cluster organization framework is proposed and a scheme for continuously improving cluster and plant safety management via communication and cooperation at plant department level as well as at cluster level is suggested.

Keywords: safety management system, cluster safety, chemical industry, site-integrated safety, safety culture, cross-company safety procedures, collaborative safety management

1. Introduction

Systematic health and safety management has become increasingly popular amongst both regulators and employers as a central strategy to reduce accidents and illness at work (Frick, 2000). Safety management aims to do this by using managerial processes to detect and reduce
workplace hazards. The chemical industry is no exception to this rule. Since the safety of complex well-defended systems in a chemical plant is dependent upon a variety of contributory human, technological and organizational factors, managing health and safety in such companies is not an easy task. Moreover, in the (petro)chemical industry economies of scale, environmental factors, social motives and legal requirements often force companies to ‘cluster’. Therefore, chemical plants are most often physically located in groups and are rarely located separately. These clusters of chemical plants consist of atmospheric, cryogenic and pressurized storage tanks, large numbers of production installation equipment, and numerous pipelines for the transportation of hazardous chemicals. In and around such clusters dangerous goods are transported in large volumes using road transport, railway carriage, shipping facilities or pipeline transportation. Due to the rapid development of chemical technology, there is a continuous growth of ever more complex installations with more extreme and critical process conditions. The incidence and the severity of accidents tend also to increase (Khan and Abbasi, 1999).

Three kinds of accidents can be distinguished: those that happen to individuals, those that happen to organizations and those that happen to clusters of organizations\(^1\). Reason (1997) indicates that individual accidents are by far the largest in number and that organizational accidents are comparatively rare, although often much more serious. However, Reason (1997) does not mention the potentially most catastrophic type of accidents, i.e. cluster accidents, probably because of the extremely low rate at which they occur. Regrettably, such accidents do occur, sometimes with disastrous consequences. Cluster accidents can be related to linked production and/or linked delivery of services, as well as to cross-company (or external) domino effects\(^2\). The first type of cluster accidents implies cluster-related safety problems might occur as a result of divided responsibilities. Such accidents generally do not have catastrophic consequences; however resulting economic losses may be substantial. The second type of cluster accidents is the result of external domino effects and can be disastrous in terms of the loss of lives.

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\(^1\) Consequences of individual accidents mainly relate to individual employees (e.g. most work related accidents), the outcome of organizational accidents affects the entire organization (e.g. internal domino effects), and cluster related accidents have an impact upon several chemical plants within an industrial area (e.g. external domino effects). Of course, all three types of accidents may affect the environment as well.

\(^2\) A domino effect can be defined as a cascade of events in which the consequences of a previous accident are increased by following one(s), spatially as well as temporally, leading to a major accident (Delvosalle, 1996). Internal domino effects occur inside the boundaries of the plant where the domino accident originates. External domino accidents are characterized by the involvement of two or more plants. Remark that the definition of what constitutes a domino effect provided by the Seveso II Directive (96/82/EC) is limited to external domino effects.
Nonetheless, in spite of the destructive potential of (internal and external) domino accidents, and the wide array of possible domino risks which many industries face worldwide, such phenomena have received much less attention than other aspects of risk assessment. Available reports on domino effects (e.g. Kletz, Pietersen and Pietersen) describe similar multiple accident events which have taken place in the past. The worst such accident – in terms of death toll – occurred in Mexico City on November 19, 1984. It was an external domino effect involving three companies: the PEMEX plant (where the accident originated), the Unigas plant, and the Gasomatico plant. The accident claimed 650 lives and injured approximately 6400 people. Another external domino accident took place on 11 December 2005 and is known as the Buncefield disaster (Hemel Hempstead, United Kingdom) leading to 43 injuries. The main companies involved were Total and Texaco, the owners of the joint venture Hertfordshire Oil Storage Terminal which took up the majority of the space at the Buncefield complex. This accident is said to be the largest fire accident of peacetime Europe and caused huge property damage losses. Other well-known (internal) domino accidents include Beek (the Netherlands) in 1975 (14 fatalities, 104 injuries) and Vishakhapatnam (India) in 1997 (60 fatalities).

Considering both types of cluster accidents, it is obvious that both process safety and occupational safety should be dealt with to obtain cluster safety improvement\(^3\). To prevent major accidents however, preventive efforts in a cluster context should be stressed on process safety. Although process safety accidents are often related to complex failure scenarios including both process hazards and occupational hazards, the former (process-related) hazards represent a larger contribution to the possible complicated mechanisms of such accidents. Therefore, the emphasis of enhancing safety in a chemical cluster lays on the prevention of external domino effects (which are mainly related to process safety). To identify which chemical plants pose an escalation risk to one another and to which extend, software and instruments are internationally being developed. Software examples include Aidram-Cargo (Switzerland), Charm (USA), DominoXL (Belgium), Flacs (Sweden), Fred/Sheperd (UK), SAVE (The Netherlands), THESIS (USA), etc. The interested reader is referred to Reniers \textit{et al.} (2006). These tools are either used to identify the potential for domino effects and/or the resulting scenarios of major accidents. Instrument examples include the Belgian domino methodology (Delvosalle, 1998), the domino risk identification and evaluation instrument

\(^3\) Process safety hazards are those arising from the processing activities of a chemical company. Occupational safety hazards affect individuals but have generally a minor impact on the processing activities of a plant.
(IDE) which has been elaborated on request of the Dutch authorities (RIVM, 2003), the MICADO instrument which was developed in France (INERIS, 2002), etc. Furthermore, to better understand the safety issues raised in respect of clustered transportation systems, Rosmuller (2001) suggests a participatory approach for carrying out transportation safety analysis. Participatory safety evaluation processes yield a shared view of experts, thereby optimizing insights into safety aspects of alternative route infrastructure plans.

Three main justifications can be cited to be concerned with safety management\(^4\) and to draft a safety management system\(^5\) on an aggregated cluster level:

(i) Literature, e.g. Lees or Ioannidis, indicates that the prevention of large scale industrial accidents, such as domino accidents, consists of carrying out reliable risk assessment studies. However, there are no existing guidelines to advise cluster managing centres handling rational and quantitative information how to estimate the consequences of multiple plant major accidents and how to propose preventive action. Therefore, it seems logical that it should be not only individual chemical plants that elaborate managerial procedures and guidelines for preventing major incidents. The development of a management document on an aggregated cluster level dealing with cluster safety issues such as the prevention and mitigation of cross-company accidents should also be contemplated.

(ii) Nowadays, European major chemical plants (so-called top-tier Seveso plants) wishing to obtain certain permits must agree to contract external organizations to carry out single plant domino effects studies, indicating the danger of the plant towards its surrounding. Multiple plant studies are not however compulsory, and as a result are often not carried out. Given the complex nature of external domino effects and the involvement of different plants, it is very difficult to obtain all the necessary confidential information to assess such multi-plant events. Moreover, there are some difficult questions to answer before the industry is convinced of the need to enhance external domino prevention cooperation. There is the question as to who will perform the study, how will it be performed, and how will the implications of the study and the proposed preventive measures be executed. Personnel with specific expertise in terms of

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\(^4\) Safety management can be defined as the set of management activities that ensures hazards being effectively identified, understood and minimized to a level which is reasonably achievable.

\(^5\) A Safety Management System can be defined as a documented set of formal (a priori identified) tasks and responsibilities that ensure safety management and its continuous improvement to be efficient and effective.
the cluster, but independent to the cluster plants, would be able to handle such confidential information and to provide suggestions.

(iii) It is also important to mention some legal points. The Commission Decision of 17 July 2002 concerning the questionnaire relating to Council Directive 96/82/EC, i.e. document 2002/605/EC, requires the Member States of the EU to report on the implementation of this Directive (as a whole) on a three-year basis. Moreover, this report has to be established on the basis of a questionnaire or outline drafted by the Commission. One of the report requirements involves explaining a strategy for guaranteeing the exchange of appropriate information between plants as regards domino effects. However, since Seveso legislation on domino effects is relatively new and conceptual, to the best of the authors’ knowledge there has been no attempt to formulate an integrating approach for the provision of legislative suggestions on swapping domino effects information. Management guidelines concerning the exchange of information have not yet been formulated.

This paper discusses joint safety requirements and joint prevention issues and moulds them into a Cluster Safety Management System (CSMS). Although this is a rather difficult theoretical topic to discuss, the paper and its suggestions have been checked by experts with a lot of safety policy knowledge and hands-on experience. The next section offers some insights into managing chemical safety. The different types of safety management systems are explained and a framework to organize safety aspects in a cluster of chemical enterprises is suggested in section 3. Section 4 elaborates the needs and the requirements for drafting a Cluster Safety Management System. Section 5 formulates recommendations for efficiently implementing the CSMS. The last section concludes by summarizing the main strengths of elaborating the CSMS as suggested in this paper.

2. Managing chemical safety

2.1. Current state-of-the-art safety management techniques

Management systems for the safe operation of chemical plants require a system of structures, responsibilities, procedures, and the availability of appropriate resources and technological know-how. Safety in a chemical surrounding can be managed at three different levels: at factory, at plant and at cluster level. Figure 1 illustrates the difference between the latter
terms, and also differentiates between a factory and an installation. Plant B for example consists of only one factory within a single installation.

**Figure 1** Installation, Factory, Plant and Cluster

Factory-level safety includes topics such as working procedures, work packages, installation-specific training, personal protective equipment, quality inspection, etc. Plant-level safety includes defining acceptable risk levels and documenting plant-specific guidelines for implementing and achieving these levels for every factory situated on the premises of the plant. It is current industrial practice to draft a Plant Safety Management System (PSMS) to meet these goals. Cluster-level safety-related topics include defining cluster safety standards, defining safety cooperation levels, defining acceptable domino risks, joint workforce planning in the event of domino effects, joint emergency planning, the jointly carrying out of risk analysis procedures, i.e., joint hazard identifications and joint risk assessments, etc. The latter aspect can be regarded as the basis of bi/multilateral information exchange between companies with respect to impacts exceeding the company border. For more information on this subject, the interested reader is referred to Reniers et al. (2005b). The latter cluster-related topics can be documented in a type of Safety Management System dealing with these issues. In the chemical process industry, at factory level and at plant level, safety documents, guidelines and instructions, technical as well as meta-technical, are usually very well elaborated. An adapted version of Deming’s quality process (Turicchi, 2000) is often used for continuously improving safety. To optimize safety, the circular plan-do-check-act process can
be used at all levels within the industry: from top (the cluster level) to bottom (the factory level). To be able to perform the Deming process at all levels, a safety cycle structure can be established at each level and provided with communication and cooperation links between the different levels. These links are necessary for further optimization of the different levels of looping safety and for prevention of double elaboration of certain multi-levelled safety topics. Such a framework characterized by loop level safety can be arranged as illustrated in Figure 2.

**Figure 2 Loop Safety Structure on Factory-, Plant-, and Cluster Level**

![Loop Safety Structure on Factory-, Plant-, and Cluster Level](image)

Remark: It should be noticed that in figure 2 indirect risk analysis links from factory level to cluster level and indirect requirements links from cluster level to factory level do exist and are accounted for by the direct links in the figure.

Plants follow the plan-do-check-act loop at factory and at plant level because of their acquired know-how of two internationally accepted business standards, i.e. ISO 9000 (Hutchins, 1997) and ISO 14000, addressing quality and environmental management systems respectively. OHSAS 18000, the international occupational health and safety management system specification that empowers an organization to control its occupational health and safety risks
and improve its performance concerning those risks, is used to develop guidelines for working out safety management systems at plant level in the chemical industry. However, cluster-specific safety guidelines do not exist nor does an elaborated plan-do-check-act cycle at cluster level exist.

2.1. Methodology to shape cluster safety

Three different cooperation situations can occur in an industrial area. Hence, three types of Safety Management System development approaches can be discerned, depending on the will of the plants to cooperate. First, if the will to cooperate does not exist between neighbouring plants, each plant draws up its own individual Plant Safety Management System. Second, if the plants are willing to cooperate fully and exchange all possible information necessary to minimize chemical risks in their area, a Joint Safety Management System can be drawn. These two situations can be regarded as the extreme cases of the cooperation-continuum. However, the first option is by no means optimal from a social point of view since the companies do not take into consideration the fact that they belong to the same industrial area. Thus, the existence of major chemical risks as a result of other plants processing hazardous materials in their vicinity is not taken into account by the preventive and protective measures. This possibility is representative of the existing situation in the chemical industry today. The second option is to be preferred from a social point of view, but may prove utopian. Several arguments explain why this is the case: plants have often put a lot of time and effort into building their own Plant Safety Management System and therefore are not willing to switch to a new Joint Safety Management System; some data must be regarded as ‘highly’ confidential; a lot of distrust and competitiveness has often existed between the plants for a long time; etc. The third possibility is situated somewhere in-between in the cooperation-continuum. In this case, the adjacent chemical plants are willing to cooperate, but on a limited scale. In such a case, a Cluster Safety Management System can be elaborated. To date, no such management system exists in the chemical process industry. For a better understanding of the different possible situations of neighbouring chemical companies, a plant spectrum can be drawn as in Figure 3.
Figure 3 illustrates the cooperation behaviour spectrum of adjacent plants and associates the type of safety management system with it. Should it be the case that two competing plants have a conflict-situation, e.g. because some personnel have left plant A to go and work at plant B, then there is a problem-inducing situation that can incite companies to restrict themselves to the implementation of individual Plant Safety Management Systems. Although most neighbouring companies do not find themselves in such a conflict-competition situation, plants today still have individual safety management systems. This is due to the fact that there is, regrettably, no other option available to the chemical industry. If plants A and B are on good terms and are also already cooperating, a Joint Safety Management System could be installed in this area. In fact, a Joint Safety Management System can be drawn the exact same way as a Plant Safety Management System since the safety measures taken by the constituent plants can be regarded as those of one big plant and the features of the Joint Safety Management System are the same for all participating companies. In most cases however, in practice the situation will be a relationship between the single plants which is characterized by the installation of a Cluster Safety Management System. The latter gives directive to the participating companies as to how to minimize cluster chemical hazards, this way optimizing continuous improving safety in the industrial area.

To make use of the know-how already available in single plants, the Cluster Safety Management System can be based on individual Plant Safety Management Systems of companies belonging to the cluster. In the first stage, the various participating plants give input to the Cluster Safety Management System guideline. This way, the Cluster Safety
Management System adds divergent company processing activities and divergent views of the individual plant safety managers to the cluster safety items list. Cluster-typical safety issues can be collected as well at this stage. The second step offers a cluster tailor-made directive for application within every individual plant. The existing Plant Safety Management System is adapted if necessary and extra cluster safety issues are implemented in the plant. For a better understanding of the method concept, see Figure 4 which illustrates the situation for the chemical cluster represented in Figure 1.

**Figure 4** Developing a Cluster Safety Management System directive for a 7-plant cluster

Depending on the severity of the potential accident consequences (e.g. resulting from the application of a domino effect instrument), plant management or governments might decide to establish such a cluster organization.

The next section describes how continuously improving safety topics at cluster level can be organized according to a tentative framework.

**2.2. A Cluster Organization Framework**
The strategic goals as laid down in a safety policy are implemented through the use of a Safety Management System. The company safety culture\(^6\) or the cluster safety culture should be brought in accordance to this safety policy. In a cluster safety management system, cluster safety requirements and safety standards should be included with the objective of ‘translating’ these to plant level and ultimately to working procedures at factory level.

In the case of a PSMS/JSMS, it is very important that this policy is clearly communicated to employees and relevant contractors in order to make them aware of their roles, responsibilities and accountabilities with respect to plant safety. In the case of a Cluster Safety Management System, the safety policy document is of a more holistic nature, emphasizing the important role of commitment, communication, cooperation, cluster responsibilities, domino or cross-company accident prevention, joint emergency preparedness, joint safety training, etc. Such a policy is best reviewed regularly and updated in the light of incident experience and any relevant changes in safety knowledge, technologies, laws and regulations.

The objectives for developing a Safety Management System, whether to enhance plant/joint safety or cluster safety, are first to minimize the likelihood of an accident, second to mitigate as conscientiously as possible potential consequences of accidents through emergency planning, land-use planning and risk communication, and third to limit the eventually adverse consequences to health, the environment and property in the event of an accident. In case of a Cluster Safety Management System, the term ‘accident’ denotes a major cross-company accident. To meet these goals, the Safety Management System addresses the appropriate actions that should be taken by the plant or by a group of plants, and by public authorities, communities and other parties involved. To proactively reduce future incidents, it also includes guidelines for implementing actions learned from the experiences of past accidents and other unexpected events.

Summarizing, a plant/joint or a cluster safety management system is characterized by prevention, preparedness, response and follow-up of accidents caused by equipment operated, or people operating within the premises of the plant or the cluster.

\(^6\) The safety culture of an organization is the product of individual and group values, attitudes, competencies and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization’s health and safety programmes. Organizations with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficacy of preventive measures (HSE, 1991).
Responsibility for the issues to be added to the Plant Safety Management Systems for developing cluster safety guidelines can be assigned to an independent body. This way no one company is favoured and the reluctance of companies to give the required data is reduced. In fact, such a body should be responsible for developing, maintaining and revising the cluster safety management system as well as monitoring its implementation. To do this, relationships between various types of organizations have to be defined on different levels. Moreover, responsibilities and decision-makers have to be assigned within these relationships. Hence, designing such an extended Safety Management System is by no means an easy task.

To organize a complex hybrid structure such as a whole chemical cluster consisting of a group of organizations, we need to unambiguously define the term ‘organization’. We view an organization, in the case of a chemical company, as a system. According to Daft (2001), a system can be defined as a set of interacting elements that acquires inputs from the environment, transforms these inputs, and discharges outputs to the external environment. The need for inputs and outputs reflects dependency on the environment. Interacting elements imply that organizations depend on one another and must work together, in the case in question on cluster safety issues. Moreover, a system is made up of several subsystems, performing the specific functions required for organizational survival, such as production, maintenance, human resource, management and safety support. The production subsystem produces the outputs of the organization. Maintenance subsystems are responsible for maintaining the smooth operation of the production processes of the organization. The human resource subsystem deals with the organization’s personnel issues, as well as with skills, training and education. Management (top- and line-) coordinates and directs the aforementioned subsystems of the organization. Management is also responsible for safe operation within chemical plants and line-management in the end makes up the balance between production goals and safety targets. Although safety support is part of the general management of an organization, it is at the same time independent from other parts of the organization. Safety support has some specific safety-related tasks such as carrying out risk analyses, drafting and updating safety documents, safety auditing, safety training, safety communication, etc. In this article, due to its independent nature, safety support is regarded as a distinct subsystem, responsible for certain safety issues in all the other subsystems, including management. Within an organization, the subsystems are interrelated, cooperate and exchange a variety of information to achieve the organization’s goals.
Since every chemical organization or ‘system’ consists of subsystems having approximately the same know-how, sharing information between such sub-organizational subsystems in a cluster can be justified. To the mutual advantage of these subsystems, their expertise and experiences can be expanded to cluster level. Figure 5 illustrates the optimizing framework that can be used for optimized cluster organization of the cluster proposed in Figure 1, and taking into account the scheme from Figure 4.

**Figure 5** Framework for optimized cluster organization

Remark: for legibility reasons, some abbreviations are used in figure 5: TT = Think Tank; CC = Cluster Council; PSMS = Plant Safety Management System, CSMS = Cluster Safety Management System; Prod. = Production; Maint. = Maintenance; H.R. = Human Resources; Man. = Management.

In Figure 5, the cluster is composed of 7 companies or ‘systems’: A, B, C, D, E, F and G. Each of these systems is composed of 5 ‘subsystems’ (or plant departments). Thus, systems are nested within systems.
Four levels of analysis normally characterize organizations (Daft, 2001). The individual human being is the basic building block of each organization. The next higher system level is the ‘subsystem’ or the department. These are collections of individuals who work together to perform group tasks. The next level of analysis is the organization itself. An organization is a collection of five subsystems that combine to form the total organization. Organizations themselves can be clustered together into the highest level of analysis, which are the inter-organizational set (called the ‘cluster’) and the community. This cluster set is the group of organizations with which a single organization interacts. To describe an optimizing approach that deals with cluster safety, a focus on the inter-organizational level of analysis is needed, paying special attention to organizations and subsystems. A ‘Cluster Council’ could streamline this multi-organizational level of analysis. How this can be achieved is explained more thoroughly in section 3.2.

Chemical companies recognize the necessity for improved cooperation (Reniers et al., 2005a). Companies are convinced of the safety maximizing synergy effects of cross-company risk analysis, but at the same time openly question the feasibility of more intensive co-operation for several reasons. First, companies belonging to an international group with standard safety methods are often obliged to use these methods. Second, companies with divergent core activities need to be convinced of the safety gains of joint safety management. Several companies were, however, convinced that joint training courses and safety drills would improve safety. Third, the desire to collaborate is often limited by practical problems, such as the procedure to purchase personal safety equipment. The fourth reason is the division of the costs of joint prevention measures, especially where mutual risks are not equally divided over the plants and are difficult to measure. These considerations and the confidentiality of company safety data are the major hurdles facing collective risk analysis in the chemical sector. Commitment and communication are key factors in enhancing cooperation and information exchange to improve internal and external safety. Once cluster safety commitment and cluster safety communication are accepted as company key notions, cluster safety cooperation can be streamlined as explained in the next section, giving recommendations to overcome the hurdles mentioned by Reniers et al (2005a).

A Plant Safety Management System aims to ensure that the various risks posed by operating the facility are always below predefined and generally accepted company risk levels. An effective Plant Safety Management System adopts a systematic and proactive (and thus anticipative) approach to the evaluation and management of the plant, its products and its human resources. To enhance process safety, the Plant Safety Management System considers safety features throughout process selection, process design, plant realization, commissioning, beneficial production and decommissioning. To enhance workforce safety, both personal and group safety equipment is provided, training programs are installed, and task capabilities are checked. Arrangements are made to guarantee that the means provided for safe operation of the industrial activity are properly designed, constructed, tested, operated, inspected and maintained and that persons working on the site (contractors included) are properly instructed.

A Cluster Safety Management System consists of subjects raised in the plant safety management system and additional cluster safety topics. By using this approach, the Cluster Safety Management System is characterized by the same safety implementation features as the Plant Safety Management System and furthermore uses these common features to address cluster safety issues as well.

Several guidelines and best practices for designing and implementing Safety Management Systems in individual chemical plants are available. In this paper, the requirements and recommendations of four of these documents – i.e., Code of Practice on Safety Management Systems for the Chemical Industry (2001), Process Safety Management (2002), Organisation of Economic Cooperation and Development Guiding Principles for Chemical Accident Prevention, Preparedness and Response (2003) and General Guidance on Risk Management Programs for Chemical Accidents Prevention (EPA, 2004) – are used. These codes of good practice applying to individual major hazard plants in the process industries are compared, analyzed and validated in the light of cluster chemical safety. Four indispensable features for establishing a single- or multi-company Safety Management System can be listed: (i) Parties involved; (ii) The Safety policy – objectives (PLAN); (iii) List of actions to be taken (PLAN-DO-CHECK-ACT practical recommendations); (iv) Implementation of the system.

In the next subsections, our view on how to elaborate a Cluster Safety Management System is discussed and recommendations are formulated.

### 3.1. Parties involved
The guidelines for plant-, joint- and cluster safety management systems should include all stakeholders involved in safety management in hazardous industries, each stakeholder having different responsibilities. Therefore, the drawing up of a PSMS, a JSMS or a CSMS takes into account the viewpoints, the tasks and the responsibilities of several groups, as represented in Table 1.

<table>
<thead>
<tr>
<th>Stakeholder Category</th>
<th>Plant</th>
<th>Public</th>
<th>Public Authorities</th>
<th>Emergency Responders</th>
<th>Other</th>
<th>Neighbouring Plants</th>
<th>Cluster Council</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stakeholder group examples</strong></td>
<td>Owners, shareholders</td>
<td>Managers, labour force</td>
<td>all the people who could be influenced by a hazardous event (external to the plant or cluster of plants)</td>
<td>authorities at national, regional and local level</td>
<td>firefighters, medical emergency responders</td>
<td>research institutes, labour organizations, business organizations</td>
<td>Plant safety managers from companies belonging to the same industrial area</td>
</tr>
<tr>
<td>PSMS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>JSMS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>CSMS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

A great deal of attention is paid to the participation and the involvement of all plant, respectively plants, employees in drawing up and implementing a Plant Safety Management System, respectively a Joint Safety Management System, as they have extensive hands-on knowledge which can be used in the process. In addition to plant line management, top-level management and the Cluster Council in particular are very important stakeholders when it comes to implementing a Cluster Safety Management System. At present, informal gatherings of companies belonging to the same industrial cluster are (slowly) evolving towards more formal organizations discussing operational practices. Examples are the ‘Deltalinqs University’ which was founded in the port of Rotterdam in 2001 and the ‘Delta Process Academy’ (DPA) founded in the port of Antwerp in 2005, ports hosting two major industrial chemical clusters in Europe. Although these initiatives are still quite informal, they express the willingness of the major players to cooperate on operational safety.

Some formal initiatives for intensive operational collaboration within chemical areas have already been initiated. To indicate the novelty of the approach explained in this paper, a conceptual comparison was carried out with two existing approaches.
The first approach we discuss is the ValuePark® concept developed by The Dow Chemical Company (ES1, ES2, 2008). Dow implemented the concept in Terneuzen (The Netherlands) and near Leipzig (Germany). These projects by Dow are inspired by the ‘Major User’ principle, indicating the industrial area to be dominated by a so-called major user (i.e., The Dow Chemical Company), and to serve as investment area for medium sized enterprises. The approach of the concept is to get preferred investors jointly settle in the ValuePark with the objective of creating synergy effects and improving the competitive situation on the market. Three main synergy effects are envisioned: (i) integration of material flows and logistic services, (ii) joint use of available infrastructure, and (iii) decreasing the necessary investment capital. Concerning safety and security within the ValuePark®, a distinction is made between mandatory services (fire department and security services) and optional services (medical services, industrial safety, industrial hygiene, and staff training) provided by the Major User. Hence, the concept is strictly concentrated on operational collaboration as regards linked production and linked delivery of services (e.g. safety services) within an industrial area provided by the so-called Major User of the area. Therefore, the objectives of the ValuePark® cooperation projects regarding safety do not aim to continuously improving the area’s safety through integrated and equally appreciated operational and procedural collaboration of chemical company neighbours, but the ‘smaller firms’ depend on the ‘Major User’.

The second approach concerns an industrial symbiosis at Kalundborg, Denmark. The philosophy behind the symbiosis of Kalundborg is that companies exploit each other’s residual or by-products on a commercial basis. Hence, the operational cooperation results in reduced consumption of resources and a significant reduction in environmental strain. Although the industrial symbiosis implies co-existence between diverse organizations in which each may benefit from the other, the individual agreement within the collaboration concept is based on commercial (and to a lesser extend environmental) principles. Some conditions for cooperation are believed to be required for the Kalundborg experience (ES3, 2008), i.e., (i) the companies must fit each other, (ii) the companies must be located near each other, and (iii) there must be openness between the companies. As a result, this industrial symbiosis initiative (i) does not focus on cluster process safety issues at all and (ii) can not be generalized to other industrial complexes (because there should be openness and mutual trust between the organizations). Therefore, the Kalundborg project can not be implemented in cases such as e.g. the Houston, the Antwerp or the Rotterdam chemical clusters since in these clusters there is much less openness, mutual trust, etc. than in Kalundborg.
A telephonic enquiry was carried out for the two existing approaches (the ValueParks® and Kalundborg) to investigate the possibility of generalizing these collaboration initiatives to other clusters and to verify the correctness of our web-based conclusions.

In the ValueParks®, the Major User offers its occupational safety know-how and knowledge (free of charge) to the firms belonging to the Park. Training sessions, fire prevention activities and/or systems, etc. are jointly organized. Safety expertise always sets out from the Major User. However, process safety know-how is not exchanged.

In the case of Kalundborg, safety is discussed by the safety advisors of the participating firms in informal gatherings. During these meetings, operational collaboration initiatives are launched to further improve occupational safety. Cooperation concerning process safety issues does not exist between the firms of the Kalundborg symbiosis initiative. Furthermore, according to the Kalundborg expert, the initiative can not be generalized to another chemical cluster without carefully taking the cultural fit of the firms constituting the cluster into consideration.

In this article, we discuss a concept for continuously improving safety within an industrial area, irrespective of the relationship between the companies constituting the cluster. The added value and the validity of the approach elaborated in this paper thus comprise (i) the focus on cluster process safety collaboration between equally appreciated partners, and (ii) the general applicability of the suggested concepts, independent of the companies’ existing cultures.

A more profound safety cooperation requires intensive collaboration at operational and coordination level (supported by top level management) where it should be guaranteed that specific data is treated confidential. These objectives can be achieved by a Cluster Council composed of company representatives and independent experts. The concept of splitting the Cluster Council into two parts was cross-checked by safety inspectors belonging to the Flemish government (Administration Environment, Nature and Landscaping, AMINAL), as well as by a company expert belonging to the Delta Process Academy and the head of the safety department of a major international chemical company.

All experts agree concerning the soundness and the potential of the suggested theoretical cluster safety approach. Using existing best industrial practices from single chemical companies and integrating them into a best cross-industrial practice for continuously improving safety within industrial areas is believed by the experts to be the only possible methodology/way for bringing theory into practice. Some critical questions about the practical
implementation of the theoretical approach were however mentioned and concern (i) the financial requirements of the Cluster Council to be effective (administration costs, training costs, audit costs, etc.), and (ii) the legal aspects and responsibilities of the Cluster Council. If possible financial and legal concerns of chemical companies belonging to a cluster can be adequately dealt with the experts are convinced that the suggested approach can lead to ‘an industrial area safety situation of the next generation’.

The authors of this paper would like to indicate that discussing both financial and legal aspects of setting up a Cluster Council and a Cluster Safety Management System fall out of the scope of this paper and are subject of future research. These issues can be treated by the individual companies belonging to a chemical cluster depending on individual situations, local circumstances and law, companies’ cultures, etc.

All members of the expert panel considered the approach of the Cluster Council to be necessary to guarantee the confidentiality of information to be respected, thereby lowering the suspicion of participating plants and making the concept of a Cluster Safety Management System more feasible. In the next subsection the concept behind the Cluster Council is explained in more detail.

3.2. The Cluster Council (CC)

To structure safety issues at a cluster level, cluster-related coordination is organized by a ‘Cluster Council’, grouping organization representatives and independent delegates. Hence, the Cluster Council consists of two parts. One is mainly composed of plant representatives and has a typical counselling function, formulating safety recommendations as a result of joint Think Tank brainstorming and communication sessions. The other part, the Cluster Council Data Administration, is composed of independent consultants responsible for administering all necessary information gathered from the different plants constituting the cluster.

A Cluster Council Think Tank organizes brainstorming sessions for the plant subsystems’ departments of Production, Maintenance, Human Recourses, Management and Safety Support. The number of participants of such a Think Tank is deliberately limited with a view to maximizing output efficiency. If the number of plants in the cluster is too large, a method of systematic alternation of representatives can be used. As a guideline, seven representatives per Think Tank are proposed: six subsystem representatives (after a fixed period of time one
representative after another alternating with subsystem representatives from the other companies) and one independent consultant with expertise in the subsystems field. The Cluster Council Safety Support Think Tank aims at achieving integrated preventive cluster safety by drawing and proposing standardized procedures (together called the Cluster Safety Management System) based on plant subsystems recommendations and added cluster safety issues. The crucial role of the safety support subsystem Think Tank is reflected in its composition, i.e. permanent cluster safety specialists from the most dangerous companies are added to the small group of seven. The Safety Support Think Tank maximum consists of twelve group members, the numbers again being limited for the same reason as previously. The Cluster Safety Management System is translated and implemented at individual plant level by the subsystems. Hence, a continuous improvement of drafting the different parts of the Cluster Safety Management System and the Plant Safety Management Systems is achieved by optimized communication and cooperation of every subsystem of the cluster.

The collection of cluster data (e.g. incidents, accidents, etc.), for inspecting plants compliance with cluster recommendations, for auditing plants towards cluster safety and for performing all kinds of administrative tasks, can be supported by a ‘Cluster Council Data Administration’. Such an administration works closely together with the Safety Support Think Tank and includes independent external safety-, Decision Support Systems- and inspection & auditing experts.

By splitting the Cluster Council into a part composed of plant personnel, i.e. the Think Tanks, and a part composed of independent experts, i.e. the Data Administration, balance between confidentiality and information sharing is targeted. The Think Tanks and the cluster organizing framework ensure the continuous improvement in taking preventive measures as regards cluster topics and, to a lesser extent, single plant safety topics. The Data Administration collects the necessary (confidential) technical installations and processes data, incident and near-incident data and uses this information as input for carrying out Decision Support Systems (i.e., computer-automated software), audits, inspections, etc. Based on the output, the Cluster Council Data Administration gives guidance and recommendations to the Cluster Council Safety Management Think Tank. Moreover, if calamities should occur having a possible impact beyond the originating company, the necessary data of all the plants is centralized in the Cluster Council Data Administration Databank and can be used without any delay.
Figure 6 combined with Figure 7 illustrate the Safety Management Systems communication- and cooperation procedure, offering a loop for continuous improvement of cluster safety.

**Figure 6** Design of an optimizing structure for Cluster Council composition

![Diagram of optimizing structure](image)

**Figure 7** Circle of continuous improvement of cluster safety

![Diagram of continuous improvement](image)

*Remark: for legibility reasons, CC was used as an abbreviation for Cluster Council in figures 6 and 7.*
Figure 7 suggests a non-exhaustive division of responsibilities of the different parts constituting the Cluster Council.

4. Practical recommendations for achieving plant or cluster safety loop of continuous improvement

To create a solid safety management system, two separate safety cycles should be elaborated: one aimed at preventing chemical accidents of any kind and one aimed at mitigating the consequences of a chemical accident in the unfortunate scenario of error. The necessary actions resulting from drawing up a safety management plan can thus be divided into three main categories:

(a) Prevention of chemical accidents
(b) Mitigation of chemical accidents
(c) Follow up and corrective actions

Therefore, these issues must be included in the PSMS/JSMS or the CSMS. In the suggested framework, these three categories are treated by the same Think Tanks. This way, information concerning prevention, mitigation and follow-up of safety related topics within the cluster context is processed in an integrated manner.

4.1. Prevention of chemical accidents

The essence of accident prevention practices consists of safety data, hazard reviews, operating procedures and training. These elements need to be integrated into a safety management document which is implemented in the plant or in the cluster on an on-going basis. To enhance implementation efficiency, the latter topics are divided into 11 subjects. The subjects recommended for drafting a Plant Safety Management System or a Joint Safety Management System, briefly described in Table 2, can be found extensively elaborated in available guidelines such as Kwong, C.Y. et al., 2001; Canadian Society for Chemical Engineering, 2002; Organization for Economic Co-operation and Development, 2003; and Environmental Protection Agency, 2004. As a consequence these topics are not discussed in depth in this paper. For a better understanding of the additional feature recommendations required to
elaborate a Cluster Safety Management System, these topics are more thoroughly described in Table 2.

Table 2 List of actions for the prevention of chemical accidents

<table>
<thead>
<tr>
<th>Safety Items</th>
<th>PSMS/JSMS</th>
<th>CSMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Safe work practices</td>
<td>Short content: (a) the tasks of every process operator; (b) safe process operation parameters which must be maintained at all time; (c) safety precautions.</td>
<td>Additional features: Enhance cross-company knowledge about the work practices used in the different plants to improve work practice effectiveness through learning and to decrease domino risks through external information on potentially dangerous or vulnerable installations.</td>
</tr>
<tr>
<td>2. Safety training</td>
<td>Safety training is needed to create (a) safety consciousness and commitment amongst new employees; (b) necessary long-term comprehensive on-the-job training or follow-up training.</td>
<td>(a) Create cluster safety consciousness by being aware of an accident escalation leading to a disaster; (b) Cluster safety training sessions to prevent or to mitigate knock-on effects by acting ‘correctly’ in the event that a ‘dangerous’ incident/accident has occurred in a nearby plant.</td>
</tr>
<tr>
<td>3. Group meetings</td>
<td>Stimulating communication and cooperation between plant management, employees and contractors about plant safety and health topics.</td>
<td>Stimulating communication and cooperation in cross-company meetings between plant representatives about cluster safety topics.</td>
</tr>
<tr>
<td>4. In-house safety rules and regulations</td>
<td>Covering the work operations or processes in the plant (clearly documented and communicated to all relevant employees and contractors).</td>
<td>In-house safety regulations have to take into account the possibility of a domino accident caused by an adjacent company.</td>
</tr>
<tr>
<td>5. Safety promotion</td>
<td>(a) To maintain awareness amongst employees and contractors of the importance of safety and health in the plant; (b) To create a plant safety culture.</td>
<td>(a) To increase awareness amongst employees of the potential danger of their plant as a result of its role as part of a cluster, and thus of the importance of cluster safety; (b) Creating a Cluster Safety Culture.</td>
</tr>
<tr>
<td>6. Contractor and employee evaluation, selection and control</td>
<td>To select, control and evaluate contractors working with hazardous installations.</td>
<td>A cluster contractor program establishing common basic safety performance indicators needs to be drafted.</td>
</tr>
</tbody>
</table>

7 These items are non-systematically listed and hence no particular attention should be paid to their sequential order. The items sequence is merely a result of the available safety management system guidelines.
7. Safety inspection, monitoring and auditing

In-house control of personnel compliance with regulatory requirements, in-house safety rules and safe work practices. The inspection program includes committee inspection, routine safety inspection, plant and equipment inspection and surprise inspection.

(a) Monitoring by the Cluster Council to control compliance with cluster regulatory requirements concerning cluster safety;
(b) Monitoring by the Cluster Council to control the inspection programs of the participating plants.

8. Maintenance regimes

To prevent and predict problems induced by a lack of maintenance. A maintenance program includes inspection programs of machinery, corrosion control programs, work practices and maintenance procedures, training, design specs, long-term maintenance plan for periodic maintenance of critical equipment, and a control system for maintenance of critical safety devices.

Monitoring by the Cluster Council to verify the effectiveness and the long-term solid character of the maintenance programs of the participating plants.

9. Hazard analysis

To identify all possible process and operational hazards for determining the mechanisms by which they could give rise to undesired events, and to evaluate the consequences of these events on health (including public health, the environment and property).

The Cluster Council has to
(a) identify cross-company consequence scenarios
(b) identify in a standardized way individual plant risk contours and identify cluster risk contours by the objective adding up of individual risk contours;
(c) identify and analyse cross-company risks for prevention optimization.

10. Control of movement and use of hazardous chemicals

(a) Control program including procedures for proper use, handling and movement of hazardous chemicals;
(b) Through the use of Material Safety data Sheets (MSDS) employees know how to correctly receipt, issue, distribute, handle and safely use the hazardous chemicals.

Communication (database) program for cross-company information exchange on the use, handling and movement of hazardous chemicals within plants forming part of the cluster.

11. Documentation control and records/Hazard communication

(a) To easily find safety procedures for every operation, machinery and equipment in the plant;
(b) To document accidents, near-misses and incidents and to communicate the lessons learned.

Drafting a cluster database with relevant safety and danger information (at plant level) related to escalation hazards. Such a database should be accessible to every plant forming part of the cluster.
4.2. Mitigation of chemical accidents

In a PSMS/JSMS, for every factory of the plant/plants the potential emergency situations and their impacts are identified. Afterwards, a response plan is developed at factory and at plant/plants level with unambiguous roles and responsibilities for everyone. Furthermore an emergency team is composed and procedures for raising alarms, initial response to emergencies, evacuation and rescue, capability of in-house resources, first-aid planning, etc. are drafted. The ultimate Plant Safety Management System or Joint Safety Management System response plan will be tested through emergency exercises and simulations in the plant/plants.

In the case of a Cluster Safety Management System, possible escalation accident scenarios and their consequences are identified. Using these data, the participating cluster companies elaborate a joint emergency plan. Such a plan includes listing the actions necessary in the event of a particular emergency situation. In the case of cluster safety issues, at least two companies per scenario are taken into account. Therefore, coordinating cluster emergency preparedness is a rather complex matter. Moreover, the plant emergency plans described in the Plant Safety Management System consider cluster emergency issues and they should be attuned to one another. Furthermore, the involvement of the fire brigade, the police and other authorized authorities is necessary.

The cluster emergency plan contains at the very least early warning automated systems (which play a key role in countering possible domino incidents) and cluster emergency centres which can act efficiently in an unexpected situation. Emergency teams have to be formed for the different ‘Cluster Parts’, which are logically smaller sub-clusters within the whole industrial area (the main cluster). Should new equipment be added to the cluster, land-use planning guidelines are implemented and the Cluster Council is fully responsible for coordination.

An individual plant emergency response program consists of four elements: an emergency response plan, emergency response equipment procedures, employee training and procedures to ensure the plan is up-to-date. The latter two items have already been discussed. A plant emergency response plan includes information about how to communicate with the public and the local agencies in the event of an unwanted release, advice on first-aid and emergency medical treatment, and information about the plant procedures and measures for emergency response. Emergency equipment includes among other things the protective equipment for
fire fighters and medical emergency response personnel. Procedures are written down about how and when to use this equipment, how to carry out maintenance and how to conduct regular inspections.

In a Cluster Safety Management System, a cluster emergency response plan, cluster emergency response equipment procedures, cluster emergency training and procedures are elaborated. They are drafted for several Cluster Parts to ensure that, should a domino accident happen at Cluster Part A (e.g. companies A and B of Figure 1) with limited or no consequences to Cluster Parts B and C (e.g. respectively plants C and D on the one hand and E, F and G on the other), the other Cluster Parts know their involvement in the emergency program, but remain the least affected in economic terms. Therefore, distributing, handling and fixing responsibilities of necessary measurement, regulation and supply of equipment in the case of an emergency at cluster level is strictly regulated in the cluster emergency response program.

4.3. Follow-up of incidents/ incident investigation and corrective actions

Past incidents can be a source of valuable information about site hazards and the steps that one needs to take to prevent accidents from happening. Often, the immediate cause of an accident is a series of other problems that need to be addressed to prevent a repetition of the incident. Therefore, in a Plant Safety Management System or Joint safety Management System, procedures are set up guaranteeing that every incident will be reported. These procedures will indicate the criteria for the type and degree of seriousness for incidents requiring more detailed investigation.

In order to establish a cluster incident database, all incidents taking place in plants belonging to the cluster are reported to the Cluster Council. By investigating and discussing these incidents in the light of cluster safety, the knowledge gained can be shared across the different participating organizations and will contribute to better overall accident prevention. Since different plants are involved, it is advisable to first organize an internal investigation at plant level with line managers, supervisors, safety personnel and safety committee members thereby obtaining all relevant information. Afterwards, incident group meetings can be organized by the Cluster Council with a view to reporting and to discussing cross-company relevant incidents. In the follow-up of such potential inter-plant incidents, responsibilities of
the individual plants are discussed by the Cluster Council. The latter, having merely a
counselling function, offers pro-active advice to the participating plants.

Accidents and incidents that occurred five years previous to the formulation of the Plant
Safety Management System / Joint Safety Management System are reported. Relevant data
recorded for each incident are: date, release duration, type chemicals involved, quantity
released, release source, on-site impacts, known off-site impacts, weather conditions (this can
aggravate or mitigate the consequences) and the initiating events of the release. The objective
of setting up this database is to determine the facts, conditions, circumstances and causes of
chemical accidents on a plant level.

Generalizing this very important learning principle, all the incidents which occurred in the
cluster in the five years previous to drafting the Cluster Safety Management System are
reported to the Cluster Council. Moreover, the possible (theoretical) cross-company
consequences of these accidents are reported. This way, plant management is aware of the
possible disastrous consequences of ‘simple’ accidents, inducing a cluster safety culture.

5. System Implementation

After developing a plant/joint safety management system, the system is implemented in the
factories of the plant(s). Thus implementation procedures are drafted and responsibilities are
appointed. The coordination of the development, implementation and integration of the safety
management system is the responsibility of the plant’s department of prevention and
protection at work. This department must allocate adequate and appropriate resources and
personnel to each element to guarantee an effective implementation.

In the Cluster Safety Management System, the responsibilities of the various stakeholders are
documented in an implementation chapter. The chapter includes topics such as procedures for
the different companies to cooperate and procedures for sharing different levels of
information. This phase is carefully worked out by the Cluster Council in cooperation with all
the relevant stakeholders.

Implementation practices are checked on a regular basis and penalties may be considered
appropriate if a company or a person ignores its or his task. On the other hand, promotion
measures to motivate companies and to stimulate implementation of the safety rules and
regulations may also be suggested.
In order to guarantee the success of a Cluster Safety Management System, commitment of the participating companies is essential (CCPS, 1994). Commitment begins with the engagement of plant top-level management; the latter must be convinced of some major benefits arising from cooperation with neighbouring companies. These benefits include:

- improved relationship with neighbouring companies;
- an opportunity to learn from the experiences of other companies to improve safety know-how;
- improved image within society and with one’s own employees;
- improved position for negotiations with insurance industry;
- decreased probability of escalation events;
- better coordination in the event of major cross-company accidents;
- more justified legal conditions in the event of a major domino event occurring.

Support of lower management and employees is also needed. However, if top management is prepared to cooperate and to take the necessary actions, it is most likely that line management will follow suit.

Commitment should be voluntary. Company top management should have the “foresight” to recognize the importance of cluster safety. Foresight is the ability to anticipate events before they happen, and as explained by Tsoukas & Shepherd (2004) it is the crucial feature of the competent business mind. For organizations to be successful, dealing with the future should be a background organizational skill. In executing its primary task, e.g. processing hazardous substances, a chemical company acts necessarily in the present. To be able, however, to continue processing hazardous substances, it needs to be concerned not just with the present but with the future as well. In dangerous high-tech chemical surroundings, safety management and joint safety management become plant key concepts for global strategic sustainability. However, joint safety management in particular has not yet received the attention and nor the label of importance it deserves.

When expanding a Plant Safety Management System to a Cluster Safety Management System, a second emphasis lies on the communication between the companies involved. The participating companies share certain information to a certain degree, such as the kind of
hazardous chemicals used in their various production processes, the location of these chemicals, changes made to processes in particular those having consequences for the other participating plants, regular reviews of the effectiveness of the system via communication between plant safety managers, etc. Moreover, communication between the employees of the different participating companies/plants is encouraged with a view to sharing experiences and learning from other plants.

Cluster Safety Communication can be divided into two different levels, i.e. the subsystem (or department) level and the cluster level. The highest level of safety communication is needed by the subsystem level, as cross-subsystem meetings lead to a reciprocal type of communication. The structure of the subsystems allow for frequent horizontal communication, perhaps through the use of permanent teams. Weekly interaction between subsystems is required and subsystem managers are jointly involved in face-to-face communication, information exchange and decision making.

On a cluster level, communication is sequential by nature. Once the output of the subsystems has been given to the respective Cluster Council subsystem Think Tanks, these Think Tanks have to formulate recommendations and guidelines which can serve as input for the Think Tank of the safety support subsystem. The latter transforms the various inputs into procedures and rules and standardizes the Cluster Safety Management System. In addition cluster-typical safety issues are added by safety management departments and consultants. The adjusted Cluster Safety Management System document as a whole is then used as a feedback input to the different subsystems groups.

6. **Conclusions and recommendations**

This paper addresses the design, development, and organization of a Cluster Safety Management System. The paper’s objective is to offer guidance for installing a workable, effective cluster management program, fully integrated into the individual company’s safety management program, and respecting its business priorities, culture, and organization. For this reason, the paper does not present formulae or dictates instructions for implementation. Instead, it aims at providing information and suggestions to help chemical plants belonging to a cluster, to take up their responsibilities and achieve higher safety levels at acceptable costs.

When drafting cluster safety procedures or when planning risk analyses to avoid external domino effects, company confidential information has to be used. Therefore, we recommend
chemical plants to jointly establish a body at site-integrated (i.e. cluster) level, the Cluster Council, responsible for cluster safety topics and (to be workable) divided into two parts: a part comprising multiple company staff and a part comprising independent personnel handling confidential data. By implementing the suggested approach in this article and establishing such a site-integrated body composed of a “confidential part” and a “non-confidential part”, the ‘lack of openness’ - problem (remark that openness is required for successful collaboration and implementation of for example the Kalundborg initiative) is taken into consideration and solved. Using our proposed cluster approach also leads to safety improvements of companies situated within the same (large) industrial area (e.g. plants within the Antwerp cluster), but for example not situated close to each other.

The article and the frameworks presented have been cross-read by a safety expert from the Delta Process Academy (Antwerp) and from a chemical multinational. They agree that although at present the paper has a rather theoretical nature its concepts are recognized to be highly valuable and sound.

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