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A CONCEPTUAL APPROACH ON LEARNING FROM ACCIDENT BY DIRECT DISSEMINATION OF ACCIDENT INFORMATION INTO PLANT DESIGN

Siti Suhaili Shahlan[1], Kamarizan Kidam[1, 2*], Markku Hurme[3], Onn Hassan[1]

[1]Department of Chemical Engineering, Faculty of Chemical & Energy Engineering, Universiti Teknologi Malaysia, Malaysia

[2]Center of Hydrogen Energy, Institute of Future Energy, Universiti Teknologi Malaysia, Malaysia

[3]Department of Biotechnology and Chemical Technology, Aalto University, P.O. Box 16100, 00076 Aalto, Finland

*Corresponding author: kamarizan@cheme.utm.my

ABSTRACT

Major accident kept on happening in the chemical process industry (CPI) may due to poor learning causing similar accident recur. It is been claimed that the weakest link of learning from accident is related to poor dissemination of accident information. In this paper, the dissemination parts of learning cycle were improved. A conceptual approach of direct dissemination of accident knowledge into design process is proposed. In the accident information dissemination, the accident knowledge was transformed into statistical data and/or accident ranking which is a major part of hazard identification and risk assessment method/tool. Depending on the type of accident data used, the accident-based method or problem-solving method could be developed through this concept. The concept was successfully applied into chemical plant design and several systematic methods for hazard identification and safer process design life cycle have been published.

***Keywords**: accident, learning from accident, experience feedback, plant design, continuous improvement*

1.0 INTRODUCTION

In last decades, accident reporting systems have been created by using substantial resources. The main objective of data collection and reporting systems is to serve as a platform for better understanding on the causes of accident as well as creating a lesson learn which later can be used as a guideline for the development of accident prevention strategy. However, numerous catastrophic accident still happen in the chemical process industry (CPI) where in the USA the accident rate of CPI has been increasing [1], also in Asia [2, 3] and in Europe [4]. The accident rate in the CPI give the impression that the current design and safety management method are insufficient to reduce and prevent the accident from keep on happening in the CPI. It also shows that the enhancement in the process safety and design are still needed.

The complexity of the operation become the contributor to the increasing level of risk in the CPI [5]. The majority of safety problems also related to the change in the industry itself. Furthermore, nowadays, in order to remain competitive, major restructuring and cost cutting programs are implemented in the industry due to the economic downturn and low oil price. This phenomenon has led to major retracement and increased of workload. Staff retrenchment, restructuring and retirement also a factors that caused the safety knowledge within the organization to drained-off. All of this influence the process safety performance. This situation called as 'resilience engineering' [6] where the quality and quantity of safety promotion being compromised (i.e. supervision, training and maintenance). As a result, the probability of accidents is increased because of human errors and aging of plants which are not well maintained.

In practice, many opportunities for learning are lost and no long term effects are produced as a result of experience. This current problems caused the organizations to potentially losing their safety knowledge and experience. The use of learning from accidents such as safety databases is also inefficient. Because of that, within five years interval, the similar accidents tend to recur [7]. The accident occur or recur is not because of we did not know how to prevent the accident but it is due to poor dissemination of accident information as well as learning from accidents [8]. It is supported by Drogaris [9], where the studied shows that accident can be prevented by the existing knowledge since around 95% of accident causes are known and foreseeable.

Recently, the Chemical Safety and Hazard Investigation Board in their report on similar accidents in the US indicate that there are about 26 similar causes of accidents involving explosions and fires in oil and gas storage facilities occurred from 1983 to 2010, resulting in 44 fatalities and 25 injuries [10]. In depth analysis on the CSB database reported that 71% out of 75 accidents were similar causes of accidents, either recurred within the same facilities (32%) or recurred in different facilities (39%). Moreover, there are only 29% of the accidents occurred for the first time due to unique accident contributors [11]. As the number of similar accidents in the CPI is increasing, we should ask if the current learning from accident approaches are sufficient. As mentioned earlier, the weakest link of experience feedback system is poor dissemination of accident information. Should we look more on how to disseminate the accident knowledge directly into process design? In this paper, a conceptual approach on disseminating accident information to the design process is proposed.

2.0 LEARNING FROM ACCIDENT THROUGH EXPERIENCE FEEDBACK SYSTEM

Learning from accident is when the knowledge of the accident that occurred in the industry was used to prevent the recurrence of accident. To further improve the safety levels and prevent future accidents, the organizations need to learn from the accident occurred by detecting events, reflecting on them, learning a lessons from it and putting this lessons into practice [12]. Many organizations react with accident by describing it with a very simple information and due to this reason, the actions taken afterwards were ineffective [13]. After identified the hazard as a result of accident, there are several actions need to be taken in order to avoid the similar accident from reoccur and to mitigate the consequences which are by using inherently safer design to remove the hazard whenever it is "reasonably practicable". If the hazard cannot be removed, then passive protection equipment should be added, the third action is by adding active protective equipment and the fourth choice is by reliance on action by people [13]. However, learning from accidents especially in high risk industries is still a young field [14]. Therefore, more focus needs to be taken in the field of learning from experience through experience feedback system in order to improve the level of learning from accident along with the preventing the reoccurrence of accident.

Experience feedback system play a central role in any management system for prevention of accident which involving a formal channel of experience feedback which is through accident reporting, near- accident reporting and workplace inspection [15]. Based on the idea of experience feedback system, Kjellen [15] shows a cycle of learning from accidents occurrences in chemical process industry in order to generate knowledge before being disseminated back to process community. The circle of experience feedback system consists of several elements which are accident, accident investigation and reporting, data collection, data analysis/ processing, lesson learnt, information dissemination/distribution, solution/decision on prevention measures, and implementation. Based on the study, there are various factors that may hinder or facilitate the learning process such as lack of trust, openness, capability and motivated people [12]. In addition, the level of leaning itself is important and it depends very much on the accident reports such as the raw data used for the analysis. The correct accident knowledge creation rely so much on the good accident data in order to enhance the process safety knowledge. There are several approaches to actively disseminate accident information in the CPI that are commonly being practice nowadays which are by using a physical means (i.e. accident reports, journals), via electronic means (i.e. accident report in databases) and by developing accident-based safety or design tools. Accident database is the most effective way to disseminate accident information as compared to the physical means since accident database provide an easy as well as good data retrieving system [3, 16]. However, in knowledge hierarchy, these both represent lower level information as compared with analyzed knowledge. In order to get a better understanding on how and why accident occur, a number of accident cases need to be analyzed to generate the accident knowledge [17]. The used of single accident case analysis is not really effective in generating an accident prevention strategy. Figure 1 shows the knowledge hierarchy form accident prevention perspective as applied in the accident analysis.

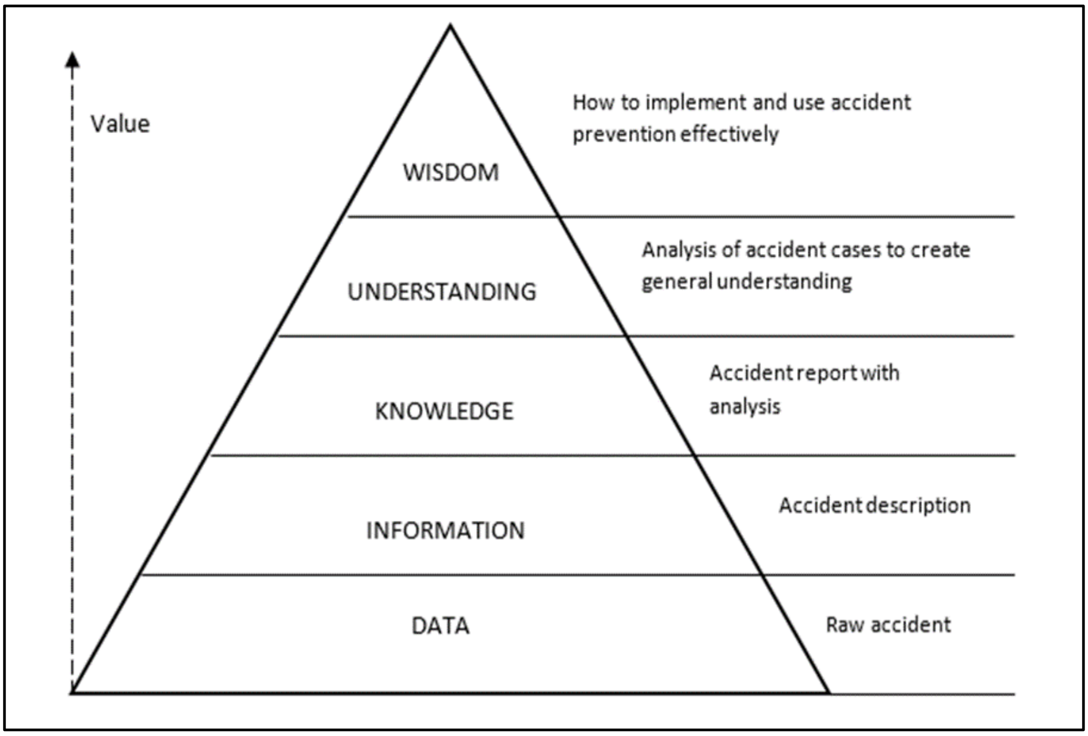

Figure 1: Knowledge hierarchy form accident prevention perspective

Better understanding on how and why accidents occur can help the industry take even more steps towards reducing the likelihood of the accident from happening in the future. But unfortunately, similar accidents keep on happening in the CPI and this is probably due to the poor dissemination of current accident information into the chemical process plant.

3.0 CURRENT RESEARCH AND WEAKNESSES OF LEARNING FROM ACCIDENT

Investigation of accident can be used as one of the most reliable and valuable sources of information for future use especially in improving the chemical plant design and avoiding similar accident from keep on happening. However, currently there are not many studies that systematically investigate the reason why organizations fail to learn in practice [18]. An in-depth analysis of the accident occurrence from the expert team can provides a detail insight into the causes of the industrial accidents and can be used for future reference. The corrective actions to address the identified causes should be done after the analysis of the incident for the successful of learning from accident [19]. It is due the fact that the repetition of the similar accident can be avoided if the causes are addressed properly. Effective learning from incidents is therefore also part of the safety management system. Moreover, the learning process mostly will stop at the reporting step while the effectiveness of learning from the reported accident always being questioned. The method and tool to identify the level of learning from incident according to how broadly the lesson learned is applied geographically, how much organizational learning is involved and how long lasting the effect of learning [20]. It also used to determine either the learning from incident in general is satisfactory or if any improvement is required. The method was found to be very useful besides giving insights of aspects that influence the learning from incidents.

The substantial injury or damage and future accident can be prevented if the industry can effectively learn from accident that happened in the past. The limiting factor that contributes to the failure to effectively learn from accident was studied [18]. Based on a model of the learning from accident they found out that learning process involving several steps which are reporting, selection, investigation, planning action and performing action. However, the finding shows that planning action becoming the most difficult phase. The gap between investigation and action for improvement should be filled in order to make the lesson learn from accident become effective. The follow up and dissemination need to be made for structural improvement. Study shows that the effectiveness of the various steps of the learning cycle such as reporting, analysis, decision, implementation and follow up (primary loop) which followed by the secondary loop that involved the compiling of the report and follow up can be used to identified as well as yielding a semi-quantitative measures (Figure 2) [21]. This framework also can be utilized for improvement and benchmarking of effectiveness of learning cycle. However, from this framework of method, it can be further refine so that the learning information can be disseminated to public and process community.

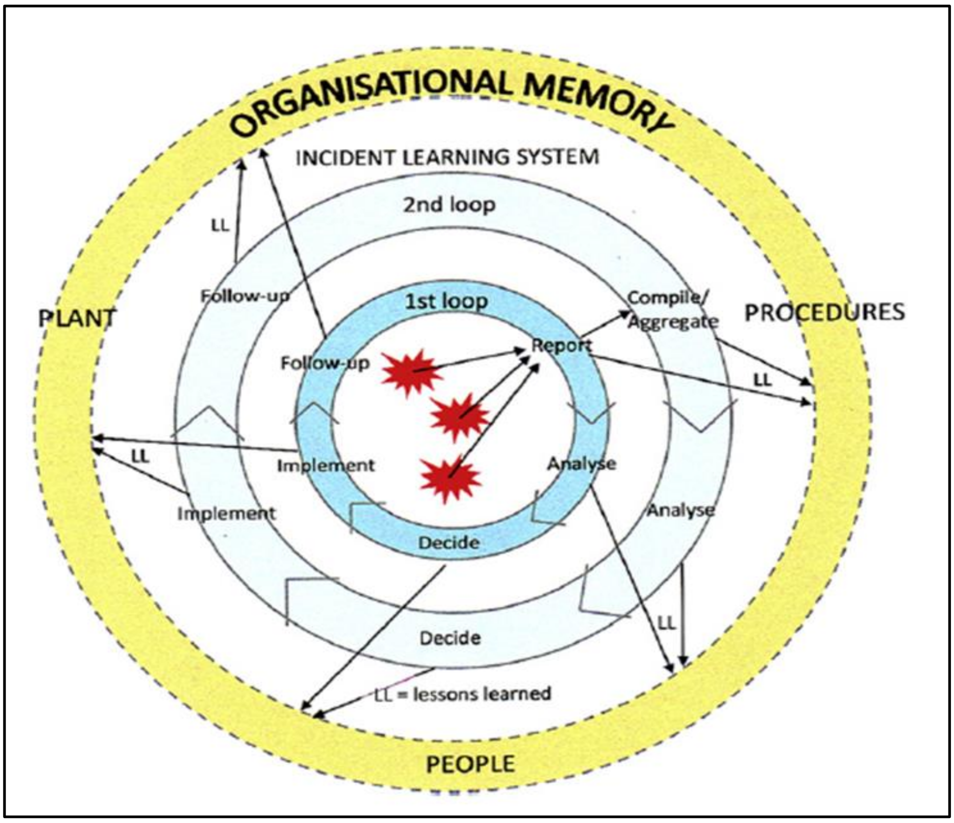

Figure 2: The learning cycle for incidents [21]

The disasters in CPI within the past years seems to show that 'we don't learn about disasters'. This situation perhaps due to the huge spectrum of interest and views on the subject of accident reporting. To improve this situation, a framework to organize the diversity of the studies was developed [14]. Figure 3 shows the various different side where the learning from accidents can be investigated. It is necessary to consider the different actors, steps and disciplinary in order to understand the learning from accidents from the widest possible angle [14]. Since the experience feedback system is a very complex process, a new method towards more integrated approach need to be developed to assisting the dissemination of information into CPI.

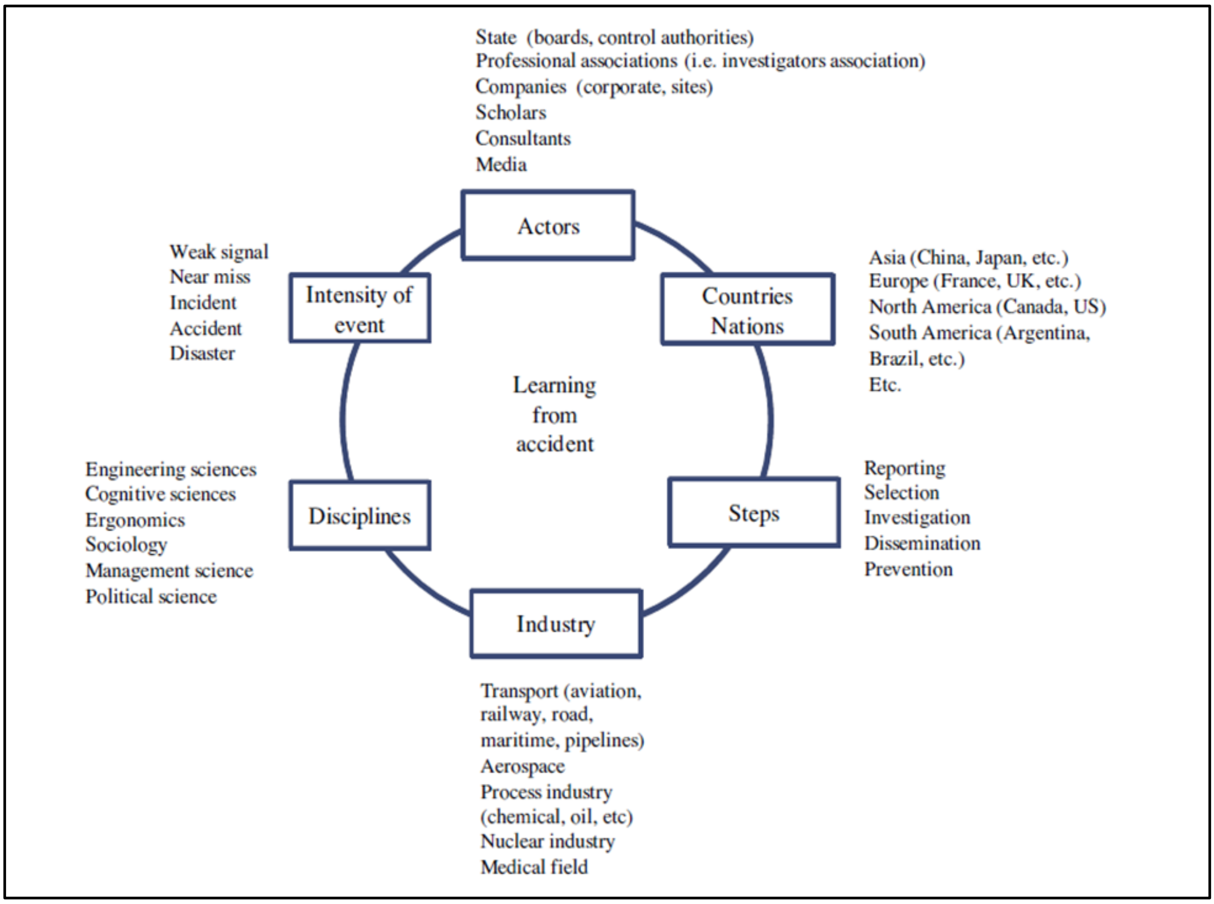

Figure 3: A Broad Framework [14]

The significant problems in the learning from accident system such as dissimilar jargon, time consuming, the accuracy of the collection method and the interfaces between human factors, technological aspects and the organization can be minimized by the development of a novel industrial accidents dataset which called as the Multi-attribute Technological Accidents Dataset (MATA-D) where the major accident reports from different industrial backgrounds will be gathered and classified under a common framework [22]. By doing this, the accidents collection will provide a rich data source and can generate input for design improvement.

As a conclusion, the field of learning from accident is still at a beginning [14] and there are still a lot of weaknesses that need to be considered. As the study at the Scandinavian refinery involving the interview with the 70 refinery employees, they found out that learning from incident need to be realized by individuals and group of employees in relation to their own work task and not only directed by a safety or incident management system [23]. Employees itself need to understand learning and the task they are expected to contribute to. Moreover, to allow continued improvement, it is important to relate the learning with the immediate causes of accident. On a broader basis, there are only one third of the accident cases studied can be considered to provide learning [24]. It is due to the several hurdles such as incomplete report, the accident was still under investigation and poor hazards identification. Kletz [8] stated that accident recur because the organization have no memory on the accident information. Base on the accident analysis [9], there are around 95% of accident causes are predictable and known. The percentage shows that the majority of accidents can be prevented by using the existing knowledge and control technology. Around 51% of the respondents believed that dissemination of the reports is the weakest link in the learning from accident cycle [25]. It is also should not be kept as a secret. The wrong interpretation of data, incorrect reporting system and misunderstanding are among the difficulties in the effectiveness of learning from accident information [26]. Thus, a framework need to be done in ensuring the current accident information can be disseminated into a chemical plant design. Major improvement or reconstruction of current dissemination practice is deem necessary. The main issue here is how to effectively learn from past accident cases?

4.0 REFLECTION

As a conclusion, because of poor input quality, lack of analysis, poor dissemination and insufficient use of accident information, the current cycle of learning system is not sufficient and effective in practice [19, 26]. Poor dissemination of accident information also becomes the weakest link in experience feedback cycle [19]. It may be due to the most of researches on experience feedback is related to accident investigation and less on dissemination of information [19]. On the other hand, most of the current accident report found to be less informative and not really beneficial enough to be used in the chemical process plant in term of learning from previous accident since only one third of the accident cases can be considered to providing a lesson learned on a broader basis [24]. Thus, the main challenge is to finding a way on how to translate the current knowledge into practice and to disseminate the accident information effectively.

The current experience feedback system needs to be modified, so that it can enhance learning. Also, it can be systematically integrated into a risk analytical method or overall risk management called accident-based hazard identification and risk assessment method [19]. Therefore in this paper, the information dissemination part of experience feedback system was modified to develop a new conceptual approach on direct dissemination of accident knowledge into design process. In plant design, accident review is a must and part of the quality control design procedure. Currently, the only method would be to search relevant accident cases in literature or databases during design work. However, the current format of accident information (e.g. accident reports and databases) is not user-friendly to the practitioners especially process engineers and designers. The search for safer design option by using the current format of accident information is demanding and time consuming. Therefore, limited utilization of past experience was made into chemical plant design.

5.0 DIRECT DISSEMINATION OF ACCIDENT INFORMATION INTO CHEMICAL PLANT DESIGN

There are series of phases in the plant design work which usually will start from research and development, preliminary process design, basic engineering, detailed engineering, construction and start-up, plant operation, retrofit, and finally decommissioning. In every design phase there will be a specific design objectives, tasks, and decisions [27]. Several safety and design reviews have been done in a process lifecycle. The quality system that defines what is done and when the engineering companies make the timing and techniques used in each company differ. As focusing in the chemical process plant design, there are number of publications that discussing and suggesting the usual timing and method for risk assessment and hazard identification [28-30]. Besides, they also identified the common methods that have been used in evaluating a safety aspects at each plant design phases. The checklists, Hazard and Operability Study (HAZOP) and hazards survey (i.e. Dow F&EI) and safety review are the most commonly used method [27, 31].

In this paper, a conceptual approach to disseminate the accident information directly into design is proposed. To disseminate accident information into design, there are three categories that have been grouped in this approach which are heuristic, case-based as well as statistical approach (Figure 4). The first approach namely heuristic is based on experience based trial and error technique. It includes design, checklists, standards and good engineering practices which used by engineers [15]. However, case-based reasoning (CBR) is a method that has been adapted to solve the current problem by reusing the information via the most similar cases retrieved. The CBR tools has been developed for accident database and used in marine safety [32]. Furthermore, the CBR was utilized to evaluate the inherent safety level of process configuration using a database of good and bad cases such as accident cases and design recommendations [33]. In the proposed approach, the most common contributors of accidents and their relations were discovered by the statistical approach. The common accident information and knowledge could be generated such as accident ranking of basic causes of accident, root causes of accident, corrective action taken to prevent similar accident etc.

Furthermore, based on usual design tasks and decisions, the time of occurrence of design and operation errors in the typical design project stages was recognized [34]. The findings were used for creating a design oriented safety method to support hazard identification activities during the design. The method aims to present the accident information on a higher-level knowledge hierarchy (i.e. understanding in Figure 1). The basic step of proposed approach is illustrated in Figure 5.

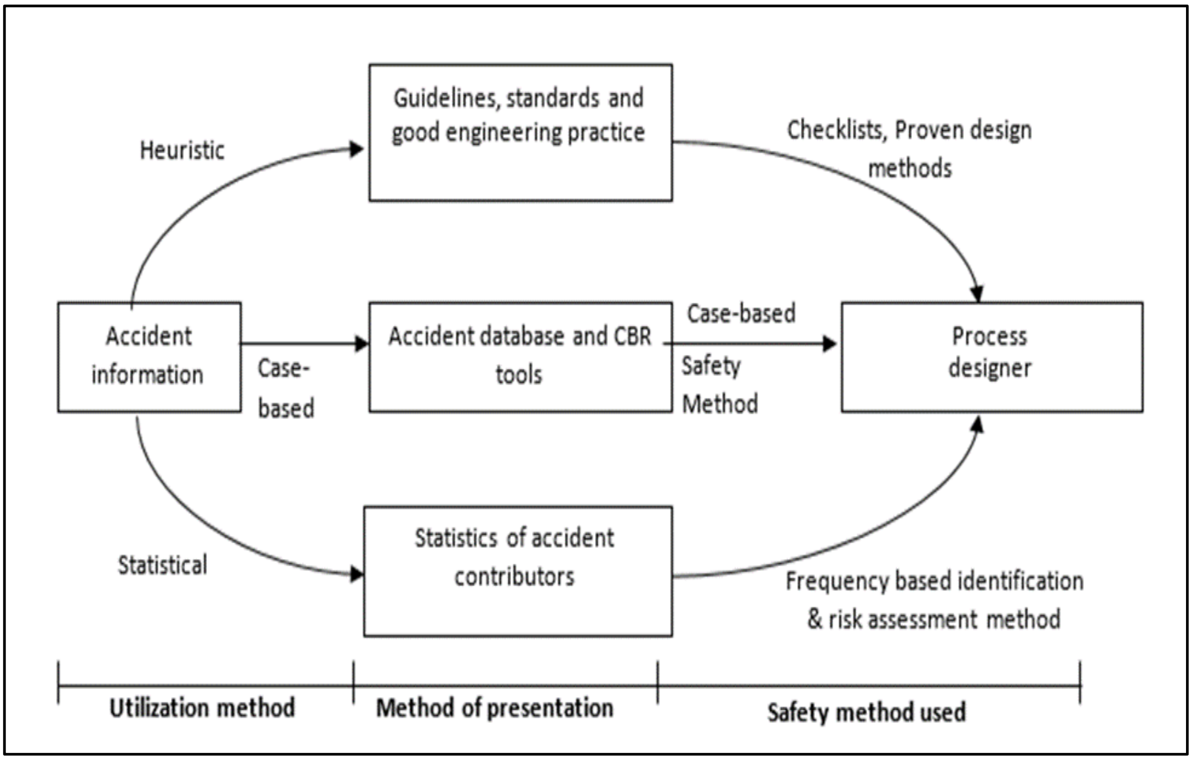

Figure 4: Learning from accident approaches with integration into design processes

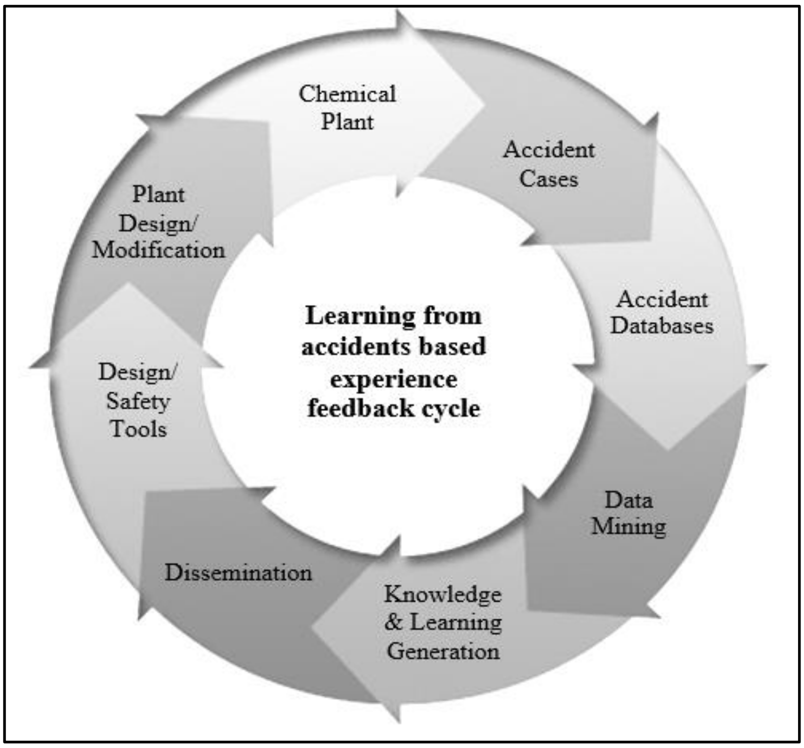

Figure 5: Improved conceptual model to enhance learning from accidents based on experience feedback system

As seen in Figure 5, the approach follows the common steps of learning from accident and experience feedback system. The system starts as following steps:

Step 1: Accident or incident occurs at the chemical plant and proper investigation and reporting are carried as usual.
Step 2: The report than were submitted to accident databases for record keeping.
Step 3: At the early stage of design, accident cases related to the new plant design is review through accident database. Data analysis or data mining are made.
Step 4: Accident knowledge were generated especially on accident causes and how accident realized. This provides better understanding on hazard and operational risk of proposed new chemical plant. Normally statistical data and accident ranking is produced.
Step 5: The accident knowledge and its understanding on how accident happen were disseminate into design/safety tools called accident-based method. The statistical data and accident ranking were used to identify the cause of accident. If the corrective action data available, the problem-solving method/tool can be develop where the cause of accident consider as problem and corrective action taken as potential solution to the problem.
Step 6: The result of the safety evaluation using accident-based method can be used as guideline for safe design during plant modification or new chemical plant design.
Step 7: As a result the accident knowledge were directly disseminated into a modified or new chemical plant. These make the chemical plant more robust to accident.

6.0 APPLICATION OF THE IMPROVED CONCEPTUAL MODEL APPROACH

The framework of the method propose in this study has been tested to validate the feasibility of this approach on learning from accident based on experience feedback system. The concept of this method has been used to conduct a several researches and four different tools have been developed and published in the Chemical Engineering Journal. Four different tools that have been developed are systematic method for identifying accident contributor [35], accident prevention approach [36], identifying error [37] and inherent safer design review and their timing [38].

6.1 Method for Identifying Contributors to Chemical Process Accidents

In this research, the knowledge on the causes of previous accident cases was utilized to identify the contributors of accidents in chemical process plant [35]. The hazard was identified base on the analysis of accident reports from the Failure Knowledge Database (FKD). From the accident data analysis, the accident contributor ranking was developed based on the general data information, the ranking is then utilized to identify the accident contributor. The method was validate by using the Bhopal tragedy and can be used throughout the process lifecycle and also in the early design stages. The proposed method was successfully identify up to 85% of accident causes as well as design and operation errors.

6.2 Accident Prevention Approach Throughout Process Design Life Cycle

A process design lifecycle approach for hazard identification was successfully applied to BP Texas City Refinery Explosion and Fire case study where 83 design and operational related errors were identified [36]. In this approach, accident data was analyzed to get the design error data. After that, the origin of design error based on normal plant design stages was identified to develop the accident ranking. The ranking was then used to identify when the error occur in plant design. Finally, the accident prevention was proposed throughout plant design lifecycle. By using the lifecycle approach, the origin of the accident contributors can be determined. It was also established that these accident contributors had occurred throughout process design lifecycle. Base on this approach, design and operational errors could be identified earlier and appropriate control at sources action could be taken as accident prevention measures. As a result, a safer and less accident-prone chemical plant could be designed.

6.3 Method for Identifying Errors in Chemical Process Development and Design Based on Accidents Knowledge

This design oriented safety method for detection of errors during process development and design was proposed and validate with the Bhopal case as well as BP Texas City Refinery Explosion and Fire case. The result shows that this method was able to identify up to 74% of design errors [37]. In this study, the design errors were ranks from the accident data analysis. The ranking was used to identify errors in process development and design. The main objective of this study is to distinguish the design errors that are usually being neglected by the designer. Result from this study shows that the method is able to identify design errors throughout process development and design. There are around 31% of common design errors associated with Bhopal plant design and around 43% in BP Texas City Refinery Explosion and Fire that have been predicted by using this method which resulted in around 74% of overall design errors. This method used the past accident information and disseminate it directly into design project. The level of learning from accident can be increase via direct dissemination of accident information into design activities. It also perhaps can be utilized to assist the designer to systematically identify the possible design error at designated design project phases.

6.4 Inherently Safer Design Review and Their Timing During Chemical Process Development and Design

The study provides a tool for a clearer and straightforward inherent safer design review (ISDR) for a safer design option generation based on the previous accident information [38]. The ISDR and its timing during chemical process development and design was discussed. The data was analyzed to identify the origin of design error based on normal plant design stages. After that, the accidents were rank to determine when the errors occurred during plant design. The ISDR was proposed based on the finding throughout plant design lifecycle. As looking from inherent safety perspectives, the design errors, point to look at for safe design and review criteria were emphasized. The potential of ISD implementation based on the frequency data was also illustrated. The timing to implement the ISDR is based on the typical plant design phases which make it easily integrated into the formal design and safety review during plant design project.

7.0 CONCLUSION

Learning from past accidents would be a great way of reducing accidents. However the utilization of accident knowledge in accident prevention is still slow and has not been effective to prevent accident. These may due to poor dissemination and poor uptake of accident knowledge into design process. In this paper, a conceptual approach on direct dissemination of accident information into chemical plant design is proposed. The aim is to enhance experience feedback on design by increasing the general usability of the accident information. This is done by transforming the accident report information into practical applications by analyzing it and creating an accident-based safety method that can be used for supporting the design activities. The concept was successfully applied into chemical plant design and several systematic methods for hazard identification and safer process design life cycle have been published. The method could identify up to 85% accident contributor and around 74% of design error. Additionally, based on this approach, common problem on design and operational errors could be identified earlier and appropriate control at sources actions could be taken as accident prevention measures. As a result, a safer and less accident-prone chemical plant could be designed.

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