# RESEARCH TRENDS ON CONTROL OF INDUSTRIAL MAJOR ACCIDENT HAZARD OCCURRENCE IN MALAYSIA: A THEMATIC REVIEW

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## ABSTRACT

*Major Hazard Installation (MHI), which involves manufacturers undertaking industrial activities with hazardous substances have been one of the important industries contributing to the growth of Malaysia's economy. However, the nature of this industry brings with it risks that can threaten human lives, property destruction and environmental pollution. The "Control of Industrial Major Accident Hazard" (CIMAH) Regulations were gazetted by the Malaysian government in 1996 as a minimum safety guidance to ensure safe operations related to MHI processes. CIMAH Regulations has been enacted for more than two decades. However, there have been limited studies looking into the issues on control of major accident regulated by CIMAH. Therefore, the study aims to review publications related to the controls of the disaster occurrence respective to CIMAH Regulations. A systematic literature review method is carried out through multiple indexing databases. Publications from 1996 to 2018 were obtained and the controls discussed in the publications are classified into five main themes. The themes are: 1) governance of CIMAH Regulations, 2) the mitigation and prevention activities, 3) quantitative risk assessment, 4) the preparedness planning and 5) recorded a major accident. This provides an overview of the evolving knowledge related to CIMAH regulation controls in Malaysia.*

**Keyword**: CIMAH, Regulations, Disaster Management, Malaysia, Major Accident.

## INTRODUCTION

The technological disaster occurrence involving hazardous materials has become a crucial issue that threatens human life, and damages facilities as well as the environment. Classic case studies of hazardous material disasters include the release of toxic chemicals such as cyclohexane at Flixborough, UK in 1974; exposure to trichlorophenol in Seveso in 1976; and leakage of methyl isocyanate in Bhopal, India in 1984. There have been 319 hazardous material disaster cases recorded from 1917 to 2011. Malaysia also has its fair share when it comes to technological disasters. This includes the explosion of a firecracker plant in Sungai Buloh, Selangor in 1991 and fire tragedy in a chemical manufacturing plant in Klang, Selangor in 1992 (Aini & Fakhru'l-Razi, 2013; Shaluf et al., 2003). Failure to manage and control hazardous materials may lead to catastrophic events.

Protecting people in the workplace and surrounding community has always been one of the primary aims of any regulations and standards. In Malaysia, Control of Industrial Accident

Hazard (CIMAH) Regulations legislation was gazetted in 1st February 1996 under the Occupational Safety and Health Act to control the risk of technological disaster occurrences due to hazardous materials. This law came into existence as a minimum requirement for industries to control possible disasters related to hazardous materials (Shaluf & Ahamadun, 2003). Malaysia's CIMAH Regulations was mainly adapted from United Kingdom's CIMAH Regulations, 1984. The major differences between the regulations were 1) threshold handling quantity of hazardous materials and 2) the role of registered "*major hazard competent person"* as recognized professional practitioner to consult MHI on the scopes of industrial major accident hazard (Shaluf & Ahamadun, 2003; Zainal et al., 2018).

The CIMAH regulations comprise of four parts formulated to control the occurrence of major hazard accidents. The first part remarks the scope of legislation for major accident hazard installation and the empowering of authorities. The second part is detailing on organizations with hazardous material properties and quantity which later classified as Major Hazard Installation (MHI). The third part illustrates the accountability of MHI to control the major accident by developing a safety case report, emergency plan and information to the vicinal community. The last part covers major accident notification and investigation.

The CIMAH regulations have been regulated for more than two decades in Malaysia. However, there has been limited research looking into CIMAH Regulations' control by MHI in Malaysia. Previous studies on this subject matter highlighted three control elements that have been studied in greater details: (1) identification of the workplace holding the hazardous material; (2) the mitigation and prevention activity; (3) the response plan (Shaluf et al., 2006; Shaluf et al., 2006; Shaluf & Ahamadun, 2003). The authors concluded that the regulations set a good minimum standard to control the risks of industrial major hazard accidents. Further studies focusing on the controls will enhance the knowledge base in the area of industrial major accident hazards in Malaysia.

The purpose of this manuscript is to provide an overview of the evolving knowledge related to CIMAH Regulation controls in Malaysia. The overview of themes and trend of publications may provide a summary of current knowledge related to CIMAH regulation controls. This may benefit stakeholders such as safety practitioners, management of companies with MHI, government enforcement agencies that are directly involved in the implementation and enforcement of controls in industrial MHI.

## METHODOLOGY

The review relies on three major databases and indexing resources- Scopus, Direct Science and Summon. There are two primary considerations in the initial extraction process of resources. Firstly, regarding the type of literature, only journal articles were selected, which mean review articles, book series, books, and chapters in the book were excluded. Second consideration excluded articles published before 1996. This is due to the fact that the CIMAH regulations were gazetted in 1996, so publications before 1996 will not be based on the finalized regulations. The inclusion and exclusion criteria are set out in Table 1.

**Table 1**
**THE INCLUSION AND EXCLUSION CRITERIA**

| Criterion | Inclusion | Exclusion |
|---|---|---|
| **Literature type** | Journal (research articles) | Conference proceeding, book chapter, book |
| **Time line** | >1996 | <1996 |

The systematic review process in this study involved four steps, adapted from the protocol by Azril et al. (2018). The first step is literature findings through keyword combinations in searching for related articles in databases. Identification keywords and terms for the search process used "*cimah AND Malaysia*" for all databases. The first step resulted in the initial identification of 28 publications. Seven publications were removed due to the literature type of conference proceeding, book chapter and book. The second step involved the screening of the identified publications. At this stage, duplicates were checked by reviewing the title of the articles, authors, years and publishers. A total of 5 duplicating publications were then excluded, after the screening process. In the third step, the reviewer was required to read the abstract to determine whether the material meets the scope of the CIMAH Regulations. The CIMAH Regulations scope limited to the industrial activities in MHI excluded the off-shore activities, nuclear activities and hazardous material transportation. After the abstract screening process, a total of 5 articles were excluded as these studies were conducted in the scope of hazardous material transportation process as well as hazardous material controls in offshore facility scenarios. The final selection process produced a total of 11 articles for further qualitative analysis. The publication selection process for this review is summarized in Figure 1.

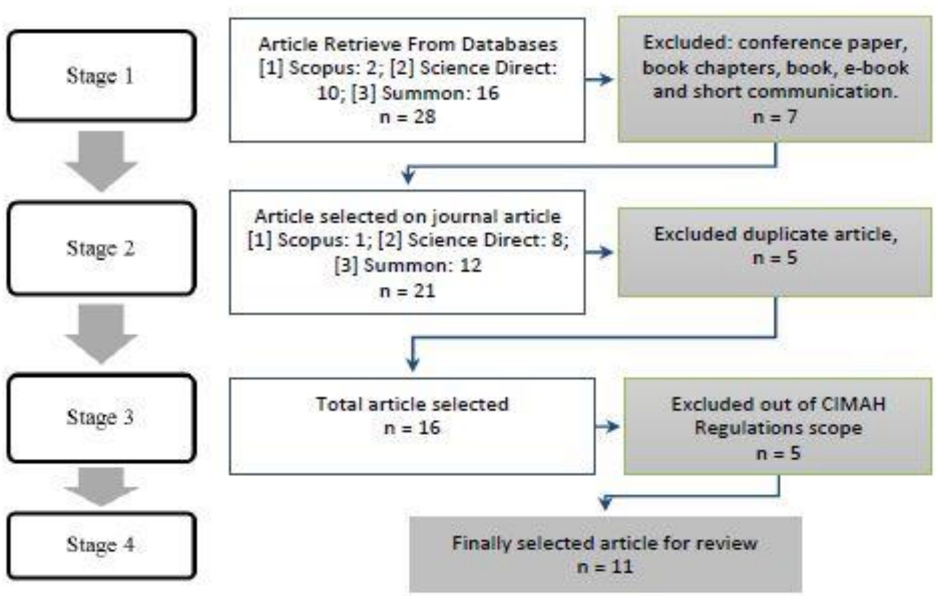


**FIGURE 1**
**THE FLOW DIAGRAM OF THE SELECTION PAPER REVIEW PROCESS**

The final 11 articles selected were then evaluated and analyzed using thematic content analysis. The thematic content analysis assists the researcher to determine the patterns, trends and themes in the literature based on the frequency of discussion topics or keywords in the literature (Vaismoradi et al., 2013). With this approach, the themes were extracted after a thorough reading of the full-text articles. The thematic codes were generated based on the keywords and discussion topics related to the type of industrial major accident hazard controls. The frequency counts of the themes were generated, which formed the basis of the content of the analysis. Following the identification of these themes, the defined theme was discussed appropriately with research team members to minimize author biases (Hosseini et al., 2016). Contextual data and information relevant to each of the theme was then compiled from the identified literature and reviewed again for analysis summary and write-ups.

## RESULTS & DISCUSSION

The article identification and selection process, after consideration of exclusion criteria, resulted in the selection of 11 papers. The earliest published articles were recorded in 2003, and the latest articles were in 2018. Through thematic analysis, the in-depth analysis of the selected papers revealed 5 main themes, which are: (1) Theme 1: CIMAH Regulations Governance, (2) Theme 2: The Mitigation and Prevention action, (3) Theme 3: Quantitative Risk Assessment, (4) Theme 4: The Preparedness Planning, and (5) Theme 5: Recorded Major Accident. Table 2 maps the selected articles related to CIMAH to the five themes identified in this study. Overall, it can be seen that all papers discussed the topic of the recorded major accident. There were some discussions on regulation governance and preparedness planning. In stark contrast, there were limited discussions on the topic of quantitative risk assessment.

**Table 2**
**THEMES ON STUDIES RELATED TO CIMAH REGULATIONS**

| | **Authors, Year** | **Theme 1** | **Theme 2** | **Theme 3** | **Theme 4** | **Theme 5** |
|---|---|---|---|---|---|---|
| | | **CIMAH Regulations Governance** | **The Mitigation and Prevention Action** | **Quantitative Risk Assessment** | **The Preparedness Planning** | **Recorded Major Accident** |
| 1 | (Shariff & Leong, 2009) | | | x | x | x |
| 2 | (Zainal et al., 2018) | x | x | | x | x |
| 3 | (Shaluf et al., 2003a) | x | | | x | x |
| 4 | (Shaluf et al., 2003c) | x | | | x | x |
| 5 | (Shaluf & Ahamadun, 2003b) | | x | | x | x |
| 6 | (Shariff et al., 2006a) | | x | x | | x |
| 7 | (Shaluf et al., 2006) | x | x | | x | x |

**Table 2**
**THEMES ON STUDIES RELATED TO CIMAH REGULATIONS**

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | (Shaluf & Ahmadun, 2006a) | x | x | | x | x |
| 9 | (Ibrahim, 2007) | | x | | x | x |
| 10 | (Ibrahim, 2008) | x | x | | x | x |
| 11 | (Aini & Fakhru'l-Razi, 2013) | x | x | | x | x |

Notes: 'x' denotes research area coverage in the article.

## Theme 1: CIMAH Regulations Governance

The review among 11 selected articles found that seven studies focused on the governance of the CIMAH Regulations. Aini & Fakhru'l-Razi (2013) in a case study is discussing the investigation of the firework factory explosion of Bright Sparklers, Sungai Buloh in 1991 that killed 26 people, reported that there was no specific law to control the risk of hazardous materials at the time, which eventually led to the introduction of CIMAH regulations. The regulations were envisioned to become a base for government enforcement as one of the controls of MHI.

According to the regulations, the Department of Occupational Safety and Health (DOSH) under the Ministry of Human Resources is authorized to administer and enforce the regulations (Shaluf & Ahmadun, 2003). This includes processing submitted reports by MHI, interviewing qualified individuals to become an industrial major hazard competent person, and conducting workplace audits and accident investigations (Shaluf & Ahamadun, 2003). DOSH's annual report in 2016 announced a total of 24,631 notices, 1176 compounds and 406 prosecution cases (DOSH, 2016). Unfortunately, the data on DOSH's specific legal actions to enforce the law with regards to CIMAH Regulations are not stated in this report.

Major Hazard Unit division consisting of trained DOSH officers was formed to enforce CIMAH laws (Shaluf & Ahamadun, 2003). However, the publication does not state how many members were recruited in this specific division. In addition, there was also no mention of what forms of training have been received by these DOSH officers. Furthermore, no documented law enforcement activities reported in the publication. In another publication, reported the lack of law enforcement with regards to CIMAH regulations was due to the lack of DOSH's human resources.

There have been studies related to emergency response plan, which indirectly can be applied as a measurement indicator on the enforcement effectiveness of the CIMAH regulations. After ten years being gazetted, a study conducted on 2006 found that out of a total of 177 MHI sites, only 20% of the MHI still did not have emergency response plans. The other 80% of the MHI sites prepared their own site-specific emergency response plans in preparation for the unfortunate industrial major hazard accidents (Shaluf & Ahmadun, 2006). The rate of enforcement achievement is encouraging, given that 80% of MHI had prepared their own site-specific emergency response plans, although 39% of the MHI self-report indicated that the emergency response plan was not relevant to them. The study provides an indirect confirmation that the CIMAH regulations' legal requirements provide authorities with a legal act to audit and initiatives to minimize industrial major accident hazard risks. As a result, this forces the MHI companies to plan and design control measures to minimize risks of hazardous material disasters.

## Theme 2: The Mitigation and Prevention Action

Mitigation and prevention activities are considered to be one of the phases in pre-disaster management cycles (Shaluf & Ahmadun, 2006). The terms "*mitigation"* and "*prevention"* are interchangeably used in several publications (Aini & Fakhru'l-Razi, 2013; Shaluf & Ahamadun, 2003).

Shariff et al. (2006) described the mitigation measures as a safety barrier built during the design for safe operation process of the hazardous material. However, it was acknowledged that the mitigation measures would increase the operating costs as they need to install and maintain protection equipment, sensors and alarm systems (Shariff & Leong, 2009; Zainal et al., 2018). Realizing this situation, researchers introduced the concept of "*inherent safer design*" in which the MHI was designed and simulated its safety features during the earlier design phase to better optimize the design of mitigation measures (Shariff et al., 2006; Shariff & Leong, 2009).

In regard to mitigation and prevention measures, CIMAH regulations require the MHI to have a management system to manage human resources, taking into account all available means to enable MHI to operate safely. This includes providing necessary training to the MHI employees. CIMAH Regulations do not specify the specific mitigation measures to be taken by MHI. This gives MHI the opportunity to use any mitigation system developed to assist MHI to control the disaster. In lieu of this, Shaluf & Ahamadun (2006) developed an industrial major hazard management system, called Technological Emergencies Expert System (TEES) to be applied in the industry, as one of the ways to comply with the mitigation initiative required by CIMAH regulations. The system was designed to assist MHI and the authorities to identify risks, as well as monitor and prepare necessary mitigation measure at a site with hazardous materials. Nevertheless, there is no further study on the use of this system, especially with regards to its suitability and limitations since it was introduced more than a decade ago.

Another management system that is synonymous with MHI mitigation measure discussed was "*process safety management system*". The purpose of the system is to curb process loss through appropriate controls of hazard relating to process (Shaluf et al., 2003). Zainal et al. (2018) in its discussion mentioned that the process safety management system had become one of the components under United States OSHA standards (Part 1910.119-Process Safety Management of Highly Hazardous Chemicals), under the purview of The United States Department of Labor.

## Theme 3: Quantitative Risk Assessment

Two of the manuscripts reviewed focus their discussion on quantifying the risk of hazardous material disaster caused by major hazard industrial activities (Shariff & Leong, 2009) & (Shaluf & Ahamadun, 2003). The hazardous material in the CIMAH Regulations is referred to any substance which has flammable, explosive, oxidizing and toxic properties. The quantity of the hazardous material, especially exceeding the number of thresholds would result in higher risks of hazardous material disaster occurrence faced by MHI (Shaluf & Ahamadun, 2003).

Therefore, the manuscripts concluded that it is vital to accurately calculate and quantify the quantity of hazardous materials, in order to evaluate the risks posed by the quantity. This risk assessment will enable MHI to take pro-active control measures. It should be noted that the specific threshold quantity of hazardous materials is one of the main differences between Malaysia's and United Kingdom's CIMAH.

Risk calculations are traditionally assessed based on two functions, probabilities and consequences. The article published by Shariff & Leong (2009) provides a formula for the risk equation and explains in detail how to apply the formula in MHI settings. The quantitative risk assessment allows illustration of the risks in numbers and quantitative figures, which would assist MHI to do a self-audit to comply with CIMAH's threshold limit. Ideally, quantitative risk assessments should be conducted before the development of MHI facilities. Nevertheless, in reality, most MHI in Malaysia has been operating before CIMAH regulations were gazetted. Thus, the quantitative risk assessment as required by the regulations can only be made while the MHI has been fully operational. As a result, initiatives and implementations to reduce existing risks require substantial financing. Kletz and Amyotte (2010) claimed that the cost of improvement at the operational stage is 1000 times higher than the level of research and development stage. The primary purpose of calculating the risk of hazardous material is to ensure that the MHI allows safe operation as specified in the CIMAH Regulations. Safe operation demonstration can also be verified using "*As Low As Reasonably Practicable"* (ALARP) risk concept (Shariff & Leong, 2009). According to the authors, MHI should ensure that quantitative risk calculations are below acceptable risk limits. As such, the authors recommended that the relevant quantitative risk assessments, necessary calculations, and projections of control measures are made at the early design stage, based on the concept of inherent risk assessment. However, the main drawbacks of the inherent risk assessment concept requiring high skill competence will be the challenge to MHI. The advantages of this concept that reduces risks with minimal costs make this approach highly valued for MHI.

## Theme 4: The Preparedness Planning

Preparedness planning is another phase of the disaster management cycle, aside from mitigation and prevention activities. Mitigation and prevention measures are founded on putting in safety barriers to minimize the risk of disaster. On the other hand, preparedness is defined as a condition of capacity and ability of MHI to take necessary actions to minimize the consequences, once the disaster started. It is the pro-active act through anticipation of the reactions required during a disaster strike. The authors continued to explain that preparedness should start with emergency response planning, followed by training for staff and emergency personnel. The emergency response plan developed by MHI is implemented by disseminating response information to all employees. In addition, preparedness would also be tested through emergency simulation exercises. The exercises can help MHI measure and assess their own level of readiness and preparedness, in cases where disaster happens.

The minimum standard specified in the CIMAH Regulations requires MHI to develop a site-specific emergency response plan. The response plan should specify step-by-step disaster response procedures, with particular response involvement from designated on-site emergency teams. Shaluf & Ahamadun (2006) reported that as of 2006, the nation had not achieved 100% compliance, as 20% of 177 MHI still did not have their on-site emergency response plans. Since then, there was no other information available to indicate the compliance level of the emergency response plan, as per CIMAH's requirements. Shaluf et al. (2003) in their review of a fire disaster case study at Tiram Kimia Sdn. Bhd, Selangor in 1992 summarized that the lack of preparedness in responding to the disaster to be one of the causes for the response team not being able to contain fire escalation from the jetty to the plant.

### Theme 5: Recorded Major Accident

Several studies have attempted to find the best and suitable definition of a major accident. Major accidents have also been referred to as technological disasters (Shaluf & Ahamadun, 2006) and a subset of man-made disasters. CIMAH Regulations define major accident as "*incident including, in particular, the release, fire or massive explosion resulting from uncontrolled development within industrial activity that poses a serious danger to the person, whether directly or indefinitely or in or out of installations, or to the environment, and involves one or more hazardous substances*". The gist of the CIMAH's definition is an uncontrollable situation that can threaten human life, infrastructure and the environment. Hence, by definition, it is not a common accident occurring in the industry such as death due to exposure to hazardous chemicals, getting run by a forklift or falling from a height.

All the articles selected in this literature review included some sections discussing the topic of the recorded major accidents. Shaluf et al. (2003) documented a series of catastrophic events occurring in Malaysia from 1968 to 2002. According to the authors, there were seven cases of major accidents in MHI, involving a total of 41 fatalities and 201 injuries. There were three major accident occurrences prior to 1996 before CIMAH regulations were introduced. The major accident occurrences recorded between 1996-2002 were four cases (Shaluf et al., 2002), involving a total of three deaths and 95 injuries. This indirectly provides an overview of the consequence severity of major accidents before and after the introduction of CIMAH regulations. The numbers indicate significant impacts on industrial major hazard disaster controls, as a result of CIMAH introduction.

Unfortunately, statistical data on major accidents in Malaysia after 2002 were unavailable. The data has not been disclosed to the public, and disclosement requires obtaining authorization from DOSH. The effort to establish a major accident database should be emulated in Malaysia, similar to the electronic Major Accident Reporting System (eMARS) database available in Europe (Zainal et al., 2018). In the eMARS system, reporting any event that fulfill the criteria of major accidents becomes compulsory for European Union (EU) member states. The major accident database will enable MHI, practitioners, and relevant authorities to exchange any lessons learned and best practices with regard to controls of major accidents. Information sharing on previous disaster cases will allow conversation and opportunity to learn to avoid repeating past mistakes, errors or failures.

## CONCLUSION

The Malaysian government has instituted the CIMAH Regulations under the pretext of controlling hazardous material disaster occurrences. Although CIMAH regulations have been around for more than two decades, the studies related to controls of industrial major accident hazard in Malaysia is still minimal. Thematic analysis on 11 articles published between 1996-

2018 on the topic of controls of industrial major hazards in Malaysia resulted in five themes which were: CIMAH Regulations governance, the mitigation and prevention action, quantitative risk assessment, the preparedness planning and recorded major accident.

This manuscript provides an overview of the current knowledge on the topic of controls of industrial major accident hazards. In summary, MHI has been given broad responsibilities to control the risks of industrial major hazards. To ensure MHI are taking the responsibilities seriously, the government has introduced CIMAH regulations under the purview of DOSH. The regulation governance gives full authorization for DOSH to ensure MHI compliances with the regulations. There has been partial data available suggesting some degree of legal enforcement and compliances. MHI is required to take necessary mitigation and prevention measures to control the risks of major hazard disaster. An expert system, as well as other procedural systems designed to mitigate risks, have been reported in several publications. Another discussion found in the literature relates to the activity of quantifying risk through risk assessment. Inherent safe design concept, which proposes risk assessment to be conducted in early design stage, would allow MHI to integrate necessary control measures early on, resulting in more effective outputs-safety and cost wise. Preparedness or readiness to respond to disasters was found to be one of the issues in the reviewed literature. Though MHI is required to prepare an emergency preparedness plan, there are still no indicators to measure MHI's preparedness if a disaster occurs. All articles touched on the topic of industrial major accident hazard records. Statistics and information on the major accident hazard occurrences and impacts have been scarce, especially since 2002. Open access database on hazardous material disasters in Malaysia may provide opportunities to exchange lessons learned and reduce repeating past mistakes for relevant stakeholders. The identified themes are expected to provide some insights to practitioners, authorities, the policy maker, MHI management, researchers, and others on the existing literature related to controls of industrial major hazard disasters in Malaysia.

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