Prevention of Major Accident Hazards (MAHs) in major Hazard Installation (MHI) premises via land use planning (LUP): a review

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Abstract. For a number of years, there is a concern about the causes of major hazards, their identification, risk assessment and the process of its management from the global perspective on the activities of the industries due to the protection of the environment, human and property. Though, industries cannot take pleasure in their business by harming the nature of the land, there are a number of measures that need to be put into consideration by the industries. Such measures are in terms of management and safety for the businesses, lives, properties, as well as the environment. The lack of consideration in the selected appropriate criteria can result in major accidental hazards (MAHs). This paper will review the land use planning (LUP) methods used in the past and present to prevent major accident hazards at major hazard installation (MHI).

1. Introduction

Major Accident Hazards (MAHs) is defined as an incident involving the loss of life that occurs within or without the site area with ten or more injuries and/or one or more injuries outside or release of toxic chemical or explosion or fire of spillage of hazardous chemical resulting in ‘on-site’ or ‘off-site’ emergencies or damage to equipments leading to the stoppage of process or having an adverse effect(s) on the environment [1]. A major accident is also defined as an “unexpected, sudden occurrence including, in particular, a major emission, fire or explosion, resulting from abnormal developments in the course of an industrial activity, leading to a serious danger to workers, the public or the environment, be it in immediate or delayed, inside or outside the installation and involving one or more hazardous substances” [2].

Several accidents such as the Bhopal tragedy on December 2nd, 1984, Mexico City on November 19th, 1984, and more recently, the Enschede fireworks disaster on May 13th, 2000, and the chemical explosion in Toulouse on September 21st, 2001, have obviously showed that how the outcomes of the industrial accidents may perhaps need to be critically reviewed to find the best solution. Thus, industries cannot take the pleasure in their business by harming the nature of the land. There are many considerations that need to be put in place by the industries, particularly in terms of its management and safety for the businesses, lives, properties, and environment. The lack in such considerations could

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very well cause major accidental hazards. Even though the industries are making various efforts, there is still much to do to enhance the policies for the purpose of reducing the dangers (impact) of major accident hazards. Therefore, this paper will review brief discussions on the issues related to the implementation of the LUP since it was introduced.

2. Literature Review
The major accident that had taken place in Bhopal (1984) arising from the leakage of methyl isocyanate (MIC) gas was the worst tragedy ever happened in the industrial process world. It was learnt that in this accident, the government of Madhya Pradesh, 2006 reported that 500,000 people were exposed to MIC gases, thus sacrificing a total of 3,787 people [3]. According to Bowonder [4], the plant was located very close to residential areas and was only 2 to 3 km from the Bhopal Railway. According to Crowl and Louvar [5], originally, the nearest civilian was 1.5 miles (2.41 km) away when the plant was constructed. However, the settlement of the population around the plant had increased so drastically that it grew very close to the plant, from 2 to 3 km to less than just 100 m away [4, 5]. Population growth in the nearby area is likely due to the fact that the plant became the most dominant job attraction in the area. The same scenario applies to the PEMEX LPG plant, Mexico in 1984, when explosions occurred from 11,000 m$^3$ of LPG until the LPG facility was destroyed and it had devastated the local town of San Juan Ixhuatepec, with 500-600 people killed and 5,000-7,000 others suffering severe burns [6]. According to Lees [7] and most reports related to the PEMEX incident, it shows that the cause of this massive loss of life is due to the siting factor of the LPG facility that is very close to the residential area. The view posed by Lees [7], that is the unreasonable plant siting factor, has been identified as one of the causes for severe impact, or the industrial accidents may perhaps need to occur as a result of the hazardous environments that had originated from the industrial locations close to the residential sites, and high-density population areas have actually been discussed from past research reports and researches through past industrial incidents such as Feyzin in 1964 and Flixborough in 1974, but there are still weaknesses in the implementation of the recommendations. Thus, this reinforces the need of land use regulations in the hazardous installations resulted in revising of Directive 82/501/EEC (the Seveso Directive) [8] that is developed under the new Directive 96/82/EC [8], to prevent MAH or minimize the consequences of accident.

The approach to having the LUP as a requirement is very reasonable since most industrial facilities are able to cause major accidents under certain circumstances with consequences extended outside the borders of the establishment and can harm human beings and the environment. Therefore, separation distance that is adequate (i.e. safe distance) to ensure the safety of human beings and the environment from hazardous activities between MHI facilities and residential and commercial areas should be taken seriously. However, the issue of separation distance needs to be carefully and reasonably refined so as not to be misinterpreted and misused, for example, if there are investors who are interested in building a chemical plant in a particular area, the authorities concerned in maintaining public safety cannot arbitrarily defend the investors on having an absurdly long separation distance without reasonable excuse(s). Therefore, a very detailed technical study that provides information relating to the potential major accidents in the form of risk assessment that may occur on MHI facilities is particularly important, so that the exact separation distance can be determined, thus avoiding extensive unexploited areas as well as economic loss.

In order to realize the element of the LUP in Seveso II Directives 1996, the European Working Group, on land use planning, composed by representatives of the Competent Authorities and appointed by the Joint Research Centre of the European Commission [5] has been established, which require that the Member States should take measures towards this direction. More specifically, Article 12 of the Directive (see Appendix V. 1) foresees:

- That the Member States shall ensure that the objectives of preventing major accidents and mitigating the consequences of such accidents are taken into account in their land use policy and especially through controls on the siting of new establishments, the modifications to existing
ones, and new developments (residential areas, areas of public use, transport links, etc.) in the vicinity of existing establishments;

- That their land-use policy takes account of the need to establish and maintain appropriate separation distances between the establishments covered by the Directive and residential areas, areas of public use and areas of particular natural sensitivity or interest;
- That the land-use policy takes account of the need for additional technical measures so as not to increase the risk to people;
- That all Competent Authorities and planning authorities shall set up appropriate consultation procedures to facilitate the implementation of the policies mentioned above (i.e. the land-use policies that take into account the major-accident hazards).

However, the above General Directives do not state clearly and in detail the exact value of separation distance. Instead, they submit to Member States and the competent authorities to determine the appropriate distance to allow the construction and operation of MHI facilities.

As a result of the process to realize these Directives, there are several constraints, among which, based on the present expansion of the European Community, only a restricted number of European countries have developed specific general guideline for LUP in relation to major accident hazards after several years from which the instructions have been introduced and enforced among Member States. Majority of European Communities still performed the control of land use planning in the vicinity of hazardous installations by non-specific legislation, and the risk is not explicitly considered within the land use policies [10-13]; it is related to another policy for the plan Economic strategic and etc. This is due to the difficulty in determining acceptability criteria of the appropriate LUP depending on the cultural background, socio-economic and the special characteristics of each region. For example, there are countries where a certain level of risk is acceptable and the LUP aims at the greater minimization of risk, as their country has very limited land area with high population rates per km² such as Hong Kong, Singapore and the likes, whereas for others, the "zero risk" concept is applied, not allowing any development which poses risk to the population, for instance, a country with very low population density.

Another factor that slowed the implementation of Seveso II Directives, 1996, was a lack in the understanding of the objective of the European Union (EU) Directive 96/82 / EC (Seveso-II Directive) among Member States, which deals with two key features of LUP; which are the separation among hazardous installations and residential, and other sensitive areas (i.e. safety distance) as well as the systematic technical framework for its assessment and scrutiny. For instance, there is no explanation from the Directive on how LUP policy should be implemented by the EU Member States into their National LUP laws, because in addition, the technical elements consist of a number of other aspects that need to be considered, such as technological, social, cultural, and economic, among others. [14]. This kind of attitude has contributed to the development of LUP hence, affecting the policy made for the protection of accident hazards in environment, while the policy is meant to be abided by all the respective countries.

Another issue related to LUP is the "domino effect", where in this issue, the interaction between neighbouring process units and plants is largely related to the MAH's risk severity chain impact, which can be avoided by adequately siting the relevant installations and planning the uses of land around them. In general, the scope and objective of LUP in the vicinity of hazardous installations is to ensure the consequences of the potential accidents are taken into consideration when decisions are made concerning siting of new installations:-

- Extension (or modifications) of existing installations;
- Determination of uses of land in the vicinity of establishments;
- Proposal for new developments in the vicinity of establishments.
To implement the Seveso Directives 1982 and Seveso II Directives 1996, the HSE of the UK implemented several guidelines such as CIMAH Regulations, 1984. The guidelines said are as follows [8]:

- Identify all the hazards involved in their undertaking, which may pose risks to personnel;
- Evaluate the risks arising from those hazards;
- Identify and put in place the means to manage the hazards and reduce the risks;
- Make a demonstration that those risks are as low as reasonably practicable.
- Under this guideline, it is also required for the risk attached to the hazardous environment be informed to persons who are within the area measured for the avoidance of the accident threat.

Nevertheless, in 2015, [14-16,18] the Control of Major Accident Hazards (COMAHs) [9], was introduced for the purpose of preventing major accidents that consist of dangerous substances and reducing the outcomes to the people and the environment. The COMAH 2015 is the realization of the main Seveso III Directive (2012/18/EU). The regulations the COMAH came into force as of June 1st, 2015 and its purpose on the other part is to assist duty holders in abiding by COMAH in the health and safety management in the most fundamentals to MAH industries. The government of Malaysia adopted the CIMAH regulations and promulgated the Regulations in February 1996, under the Department of Occupational Safety and Health (DOSH), Malaysia. Under this CIMAH 1996, Malaysia regulations, should there be any premises that process, handle, store, and manufacture the chemicals listed in Schedule 1 and 2, CIMAH 1996 in this study that exceeds the threshold equivalent quantities specified as in Schedule 2, CIMAH 1996, then the premise is required to present CIMAH Safety report from a CIMAH competent assessor according to Schedule 6 (Subregulation 14 (1) and 15 (1)) i.e. "Information To be Included In The Report on Industrial Activity". It contained a total of four components and the list presented as follows [23]:

(a) Information relating to every hazardous substance involved in the activity in relevant quantity as listed in Schedule 2.
   i) The name of the hazardous substance as given in Schedule 2 or for a hazardous substance included in either of those Schedules under a general designation, the name corresponding to the chemical formula of the hazardous substance;
   ii) A general description of the analytical methods available to the manufacturer for determining the presence of the hazardous substance, or references to such methods in the scientific literature;
   iii) A brief description of the hazards, which may be created by the hazardous substance;
   iv) The degree of purity of the hazardous substance, and the names of the main impurities and their percentages.

(b) Information relating to the installation, namely
   i) A map of the site and its surrounding areas to a scale large enough to show any features that may be significant in the assessment of the hazard of risk associated with the site;
   ii) Scale plan of the site showing the locations and quantities of all significant inventories of the hazardous substance;
   iii) A description of the processes or storage involving the hazardous substance and an indication of the conditions under which it is normally held;
   iv) The maximum number of persons likely to be present on site;
   v) Information about the nature of the land use and the size and distribution of the population in the vicinity of the industrial activity to which the report relates;
   vi) Information on the nearest emergency services (fire station, hospital, police station, community hall, etc.)

(c) Information relating to the system of management for controlling the industrial activity, namely:
   i) The staffing arrangement for controlling the Industrial activity with the name of the person responsible for safety on the site and the names of those who are authorized to set emergency procedures in motion and to inform outside authorities
ii) The arrangements made to ensure that the means provided for the safe operation of the industrial activity are properly designed, constructed, tested, operated, inspected, and maintained.

iii) The arrangements for training of persons working on the site.

(d) Information relating to a potential major accident in the form of risk assessment, which contains the following:

i) A description of the potential sources of a major accident and the conditions or events, which could be significant in bringing one about.

ii) A diagram of the plant in which the industrial activity is carried on, sufficient to show the features which are significant as regards the potential for a major accident or its prevention or control.

iii) Information about prevailing meteorological conditions in the vicinity of the site;

iv) A estimate of the number of people on site who may be exposed to the hazards considered in the report;

v) The consequences to the surrounding areas in the form of risk assessment.

The same was done by other countries such as Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Holland, Portugal, Spain, Sweden, Singapore, Hong Kong, and United Kingdom, that is, creating specific guidelines for assessing the effects of a worst-case scenario of an incident, should it occur. This information will be used to determine the hazard boundary zone that may be caused by the MHI incident and determine the acceptability site, whether the presence of the MHI facility is safe or not, as well as to determine the appropriate emergency response method.

Nonetheless, all of the above-mentioned countries have a different approach or method of risk assessment approach, namely consequences-oriented approach, risk-oriented approach, land use planning criteria and generic safety distance based on Environmental Impact Assessment (EIA). Countries such as France, Holland, United Kingdom, Germany, and Luxembourg use the land use planning criteria approach. For Malaysia, our approaches are a combination of consequences-oriented approach and LUP criteria. However, there are several new approaches, one of them being Alessandro et al. [14, 16, 20] who examined the LUP in the industrial environment as the occurrence of major accidents. The LUP was used in identifying the criteria in the accident scenarios. Generally, the appropriate choice of area in the chosen criteria of major accident would result into a critical effect in terms of assessment and the follow-up policy. The model used in developing the LUP is an improved version of MIMAHs (Methodology for the Identification of Major Hazard Accidents).

In an attempt to provide safety to the human and environment, Kyusang, Seonghyun and En Sup Yoon [21] discusses the process that can ensure the protection to land and human through the minimization of the risk and dangers of chemical process plant attached to human beings through the plants. The article further focuses on the process of providing safety measures and therefore, provides the steps that can be used at the earliest period in processing the designated plant. In addition, John and Richard [22] provides an important insight on the chemical reaction in hazards environment as the key factors to the incidents occurred in manufacturing and processes of chemical substance around the world.

Christou et al. [14-17, 19] provides the key factor summaries associated to the LUP and the role of risk management. The chapter provides two major operational scenarios that are fundamental to the LUP, that is, firstly, fixed site risk which covers storage and manufacturing facility, and secondly, transport risks which covers bulk road, rail tankers of chemicals, petroleum products, gas, and shopping. The literature provides a comprehensive explanation between the factors and their connection to each other. Furthermore, it explains the routine activities that are involved in each scenario by making reference to the itemized issues under the factors. As part of the efforts of the activities, it clearly shows that the LUP is mandatory in ensuring the stakeholders discharging their obligations. It further identifies the relevance of business and industrial facilities in LUP, where it
provides the activities that show the conceptual framework of the business and industry as in Figure 1. This is seen as an interaction between the risk and business impact, where business and residential businesses are impacted on low impact. When the risk impact increases, special attention should be taken to minimize the impact.

![Figure 1. Business and Industry Precincts - A Conceptual Framework](image)

A number of recognized, published articles had provided methodological concept in determining the LUP as the method of identification of accident scenario, whereby such concept will be adopted in this review paper. The regulations will also be used in evaluating the effectiveness of the provisions in determining high risk and safety of the entire public and environment. In a proposed procedure in the current research, the target is at the identification of the accident scenarios, which is relevant in determining LUP in the area of around major hazard institutions as classified in Seveso sites without the help of specific risk-based or consequence-based approaches that had been shortly adopted in the decisional phase of LUP (Cozzani et al., 2006) [8]. The proposed procedure is also applicable to the existing and new plants. As such, it would involve the usual effort through information required for risk assessment studies (CCPS, 2000; Mannan, 2005; Uijt de Haag & Ale, 2005). A sound basis is required in the approach to LUP. As such, it is of importance that the accident scenarios are carefully selected via a validated procedure that aims at efficient identification process of reference accident scenarios for LUP purposes. A draft table (Table 1) of various accident scenarios based on an enhanced version of the MIMAH methodology is created. Then, HAZOP analysis is utilised in validating the relevance of the draft table produced as well as other techniques applied. Subsequently, the possible accident scenarios are assessed for LUP relevance against criteria accounting for expected severity, frequency and time scale of the scenarios said [6].

Furthermore, in the case of adopting this method, an updated version of the MIMAH methodology was developed to identify possible accident scenarios, as mentioned beforehand. MIMAH is a step-by-step methodology for the identification of accident scenarios; this is usually carried out with the development of generic fault and event trees. The methodology is based on categorization of utensils and of properties of the hazardous substances, and includes a database of reference fault and event trees. The adoption of the MIMAH method approach is justified based on the rational representative of the current state-of-the-art in accident scenarios identification, since it was originally developed within the EU FP6 ARAMIS project [7]. The second stage provided a systematic procedure applied to the draft table of possible accident scenarios obtained by MIMAH to identify the relevant scenarios that should be applicable for LUP. In the first stage, the draft table is revised and integrated with the results obtained from a layered approach based on specific identification techniques. Then, the second stage
is the validation process, where practical rules are provided to select the accident scenarios relevant in the LUP context from the general list obtained in Stage I.

**Table 1.** Reference customization criteria introduced for the identification of accident scenarios

| Task | Criteria | Example |
|------|----------|---------|
| Identify hazardous equipment category (EQ) | For equipment not included in original EQ classes of MIMAH, select EQ based on geometrical and functional similarity. | Loading/unloading facilities, hoses and connection arms are considered as the likeliest geometrical class “EQ10 – pipe network”. |
| Customize the generic tree | Exclude causes due to material properties. Exclude causes due to equipment characteristics. Exclude causes due to operation characteristics. | Eliminate causes like “internal combustion/explosion” for non-flammable/reactive materials. Eliminate causes like “leak/rupture of internal high pressure source” if utilities such as HP steam coil are not present. Not consider scenarios like “filled beyond normal level” if material is in gas/vapour state. |
| Customize the generic tree | Exclude non-relevant events due to properties of the contained material. Propose conditional exclusions depending upon the verification of specific additional information. Mark with warning notes the specific scenarios that may occur only under particular enabling conditions. | Eliminate fire scenarios for non-flammable materials. Check if initial concentration and temperature of a water ammonia pool may yield toxic concentrations in air. Only the release of LNG over water can give raise to a Rapid Phase Transition scenario. |

3. Conclusions

The MAH is one of the major incidents that keep affecting the development of the environment in a destructive way. Though the MAH is always monitored, supervised and regulated by institutions meant for that, accidents remain inevitable at times. The major concern is the application of the land use planning (LUP) procedure for effective use in securing the safety of the environment, people and property. The MAH is still a threat due to its effects on the environment; this was resulted from the use of chemicals such as biological, physical and mechanical. These accidents were generally referred to as industrial sites and more often than not, some industries are in the habit of violating the land planning policies. These policies were made to ensure the safety of the operation of industries. The industries are expected to fully comply with the respective regulations in enhancing the safety of the environment, people and their properties. Usually, the result of the increasing incidence leads to injuries, loss of property and environmental degradation. Some of the accident that happens around the globe had affected the loss of a reasonable number of lives, property and environment. It had since become essential for operators to ensure the compliance of the effective measures and its proper utilisation for security purposes. I believe that the LUP plays a vital role in increasing the effectiveness of the strategies applied in curbing the ever-existing risks, even in a properly regulated site. Although each country's approach to controlling the risk of MAH is different, the effectiveness of each of the approaches practiced by the affected State is not known. Accordingly, in the authors’ view, all the MAH control approaches need to be taken into account and validated to see fit before a new approach is to be introduced, not counting if the approach in the form of criteria, guideline, code of practice or the likes of a country is to be adopted by different geographical boundaries. Thence, the process of screening all of the parameters should be done more carefully in terms of safety, economic and sustainability of the future.
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References

[1] Disaster Management Institute Bhopal, accessed on 6/3/2017, available at http://www.hrpidrm.in/e5783/e26901/

[2] International Labour Organization, “Prevention of major industrial accidents”, Geneva, International Labour Office, 1991, at p. 3. An ILO contribution to the International Programme on Chemical Safety of UNEP, the ILO and the WHO (IPCS), Geneva, Switzerland.

[3] "Madhya Pradesh Government: Bhopal Gas Tragedy Relief and Rehabilitation Department, Bhopal". Mp.gov.in. Retrieved 28 May 2017.

[4] B Bowonder, “An analysis of the Bhopal accident”, Prajeci Appraisal, volume 2, number 3, September 1987, pages 157-168. Beech Tree Publishing, 10 Watford Close, Guildford, Surrey GU1 2EP, England.

[5] Crowl D. A. And Louvar J.F, “Chemical Process Safety: Fundamental with Applications” 2nd edition, 2002, Prentice hall.

[6] Arturson, G., “The tragedy of San Juanico--the most severe LPG disaster in history.”, Burns Incl Therm Inj. 1987 Apr;13(2):87-102.

[7] Lees, F. P., “Loss Prevention in the Process Industries,” Butterworth Edited by Sam Mannan, 2005.

[8] V. Cozzani et al. “Application of land-use planning criteria for the control of major accident hazards: A case-study”, Journal of Hazardous Materials A136 (2006), at p. 170.

[9] Council Directive 96/82/EC of 9 December 1996 on the control of major accident hazards involving dangerous substances, Official Journal of the European Communities, L 10/13, Brussels, 14.1.97. [5] O’Leary S K, Foutz B E, Shur M S, Bhapkar U V and Eastman L F 1998 J. Appl. Phys. 83 826

[10] [5] M. Smeder, M.D. Christou, S. Besi, Land use planning in the context of major accident hazards—an analysis of procedures and criteria in selected EU member states, Report EUR 16452 EN, Institute for Systems, Informatics and Safety, JRC Ispra, Ispra (I), 1996.

[11] M.D. Christou, A. Amendola, M. Smeder, The control of major accident hazards: the land-use planning issue, J. Hazard. Mater. 65 (1999) 151–178.

[12] M.D. Christou, M. Mattarelli, Land-use planning in the vicinity of chemical sites: risk-informed decision making at a local community level, J. Hazard. Mater. 78 (2000) 191–222.

[13] C. Hamilton, R. De Cort, K. O’Donnel, Report on land use planning controls for major hazard installations in the European Union, EUR 15700 EN, European Commission, 1994.

[14] A. Tugnolia, Z. Gyenes, L. V. Wijk, M. Christou, G. Spadoni, V. Cozzani, “Scenario Selection for Land Use Planning Purposes around “Seveso” Establishments”, Chemical Engineering Transactions, Vol. 26, 2012, p. 417-422.

[15] M. Smeder, M.D. Christou, S. Besi, Land use planning in the context of major accident hazards—an analysis of procedures and criteria in selected EU member states, Report EUR 16452 EN, Institute for Systems, Informatics and Safety, JRC Ispra, Ispra (I), 1996.
[16] A. Tugnoli et al., “Reference criteria for the identification of accident scenarios in the framework of land use planning”, Journal of Loss Prevention in the Process Industries, 26, 2013, at p. 614.

[17] Graham Dalzell, “Understanding Major Accident Hazards – The Cutting Edge Of Common Sense”, Symposium Series No. 149, 2003 Icheme, at P 502

[18] Health and Safety Executive, “The Control of Major Accident Hazards Regulations 2015”, Guidance on Regulation. L111 (Third edition) Published 2015.

[19] M. Smeder, M.D. Christou, S. Besi, Land use planning in the context of major accident hazards—an analysis of procedures and criteria in selected EU member states, Report EUR 16452 EN, Institute for Systems, Informatics and Safety, JRC Ispra, Ispra (I), 1996.

[20] Tugnoli, Alessandro, Zsuzsanna Gyenes, Lorenzo Van Wijk, Michalis Christou, Gigliola Spadoni, and Valerio Cozzani. "Reference criteria for the identification of accident scenarios in the framework of land use planning." Journal of Loss Prevention in the Process Industries 26, no. 4 (2013): 614-627.

[21] Han, Kyusang, Seonghyun Cho, and En Sup Yoon. "Optimal layout of a chemical process plant to minimize the risk to humans." Procedia Computer Science 22 (2013): 1146-1155.

[22] John Barton and Richard Rogers, Chemical Reaction Hazards, A Guide to safety, second edition, 1997.

[23] Occupational Safety and Health Act 1994(Act 514) and Regulations, 1996, ILBS.