LAND-USE PLANNING IN RELATION TO CHEMICAL FACILITIES AND ASSOCIATED ISSUES IN THE U.S.

A Thesis

by

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ABSTRACT

Low probability, high consequence events within the oil, gas and chemical industries can have devastating effects on employees, facilities, companies, and the surrounding communities. Incidents such as the Bhopal gas leak and the explosion in West, Texas highlight the need for preventative measures such as land-use planning (LUP). LUP is the process of analyzing and assessing potential hazards in facilities to mitigate the effects of such events by taking into consideration their impact when decisions are made concerning the siting of new facilities, modification of existing facilities and the proposal for new developments near existing facilities. Unfortunately, a method of best practice for LUP in the United States has yet to be identified. Implementation of LUP is complicated by various approaches, methodologies, government enforcement and factors that must be considered. Yet, it is clear that action is necessary to protect local communities and mitigate the effects of incidents at hazardous chemical facilities.

LUP policies throughout the world have been implemented based upon the three main approaches of generic safety distances, consequences, and risks. Countries are actively practicing aspects of each approach, with the latter two used more extensively. Each approach and policy contains a unique set of pros and cons dependent upon the environment in which it is implemented. Evaluating current approaches, existing LUP policies and identifying the key elements of each are imperative to identifying possible improvements for the United States. Currently in the U.S. there are no federal

regulations encompassing LUP for hazardous chemical facilities and the land surrounding them. The authority to regulate private land use has primarily been handed down to the local communities who have historically done very little to mitigating risks. There is a lack of regulations providing guidance for owners/operators of facilities, local communities, and governmental oversight in the event of LUP issues around hazardous chemical facilities.

Jurisdiction confusion and the Fifth Amendment, among other factors, create hurdles for implementing and enforcing a LUP policy within the States. Economic diversity between the 50 states of the U.S. further complicates the issue. It would be hard-pressed to implement a single approach that works best for all states. Implementation and best practice of LUP in the U.S. may be a combination of existing approaches from other countries with built in flexibility that allows each state to choose what works best for them.

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NOMENCLATURE

AN	Ammonium Nitrate
ATF	U.S. Bureau of Alcohol, Tobacco, Firearms and Explosives
AZF	Azote de France
BEVI	Dutch Public Safety Decree
BLEVE	Boiling Liquid Expanding Vapor Explosion
BRZO	Dutch Major Hazards Decree
CAAA	Clean Air Act Amendments of 1990
CBA	Consequence Based Approach
CFR	Code of Federal Regulations
COMAH	Control of Major Accident Hazards
DOT	Department of Transportation
EO	Executive Order
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act of 1986
GHS	Globally Harmonized System
GSD	Generic Safety Distances
HSE	Health & Safety Executive (UK)
HUD	U.S. Department of Housing and Urban Development
LFL	Lower Flammability Limit
LNG	Liquefied Natural Gas

LPA	Local Planning Authority
LUP	Land-Use Planning
NFPA	National Fire Protection Association
OCA	Off-Site Consequence Analysis
OSHA	Occupational Safety and Health Administration
PADHI	Planning Advice for Developments near Hazardous Instillations
PHMSA	Pipeline and Hazardous Materials Safety Administration
PIG	Plan d'Intérêt Général (France)
PPRT	Technological Risk Prevention Plans (France)
PSM	Process Safety Management
QRA	Quantitative Risk Assessment
RBA	Risk Based Approach
RMP	Risk Management Program
TLV	Threshold Limit Value
UCC	Union Carbide Corporation
VROM	Housing, Spatial Planning and Environment Ministry (France)
WFC	West Fertilizer Company
WISD	West Independent School District

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1. INTRODUCTION

The catastrophic effects of major oil, gas and chemical incidents such as the explosion in West, Texas, have brought about a negative perception of the industry. The major contribution to this perception has been the escalation of incidents into disasters by inadequate land-use planning (LUP). LUP is the process of analyzing and assessing potential hazards in oil, gas and chemical facilities, which may pose potential conflicts with surrounding areas. The goal of LUP is to ensure that the impacts of potential incidents are taken into consideration to mitigate or prevent future disasters to the land surrounding a hazardous chemical facility. In addition, LUP is not limited to the construction of new facilities; it also applies to the modification of an existing facility and in the event of a community encroaching upon a facility that has been in operation for years. Unfortunately, a method of best practice for LUP implementation has yet to be identified.

The roots of LUP go back to hundreds of years when city ordinances separated industrial and residential zones within city limits. Traditionally, this has been enforced by permitting for subdivisions and industrial parts within city limits. This separation has been based upon nuisance effects such as noise, heavy traffic, pollution or odor; however, this approach does not account for major hazards that have led to the negative perception of the industry.

Right now, there are local communities at risk due to the operations of oil, gas, and chemical facilities. In many instances, the public is unaware of the risk they live with on a daily basis. Economic development has often taken precedence over proper LUP. The historically reactive response to safety and LUP within the chemical industry and governments has led to implementation of preventative measures or regulations only after an incident has occurred. Major incidents such as the gas leak at Bhopal, India, the ammonium nitrate explosion in Toulouse, France, the ammonium nitrate explosion in West, Texas, and the deadly explosion at a storage warehouse in Tianjin, China have destroyed communities and taken the lives of many! Yet the U.S. still does not have a policy in place to mitigate such incidents with the use of LUP. The toxic gas release in Bhopal, India happened back in 1984, in 2001, the explosion at a fertilizer factory in France, then another explosion in Texas in 2013 and then yet another explosion in China in 2015. These tragedies continue to take place and are going to continue to take place unless preventative action is taken. An EPA report points out that there were 17 toxic releases, in 25 years preceding 1989, in the U.S. that exceeded the volume and level of toxicity of the Bhopal release. However, the lack of people and establishments in the areas surrounding these releases saved casualties [1].

Unfortunately, the U.S. and even the world are far from a best practice of implementing and enforcing LUP. LUP policy is nonexistent is some countries, developing or being modified in some, and fully developed in a few others. A definitive best practice is missing, and the lack of LUP policy in some countries is disheartening. The issue of LUP is dynamic and complex in its need to address how to handle proposals for new facilities, modifications to existing facilities, and existing facilities that already pose a threat to local communities. The interest of different levels and departments of government, agencies, developers, landowners, local residents, and other members of the public and organizations complicate it even further. If LUP is, so community driven how can we incorporate big government or have a federal regulation and make it work? How can LUP be better? How can it be implemented and enforced in the U.S.?

2. DESCRIPTION OF PROJECT

This research and thesis was brought about by the clear lack of federal and state zoning laws currently in the U.S. that have cumulated into avoidable risk for local communities. Inadequate LUP has allowed communities and hazardous facilities to coexist in close proximity to each other with little regard for potential catastrophes that could ensue. It should be considered general knowledge that regulations should be in place to account for the implications of major accident hazards; however, how to implement and enforce new LUP regulation is still unknown [2].

The assessments of case studies involving incidents with a clear lack of LUP are beneficial pieces of literature to study, learn, and prove that LUP is a poignant and ongoing issue. The full magnitude of the issue at hand and the potential impact that an effective LUP policy could have are seen in such case studies. Research attention to the assessment of current LUP policies throughout the world; evaluating the various approaches, methodologies and facets of each can lead to the root causes of the problem. Furthermore, characterizing the issue and identifying the questions that must be answered before implementation of an effective policy is plausible. Answering these questions is essential to implementing an effective LUP policy in the U.S. The study of past and current LUP policies throughout the European Union with the Seveso Directives, in addition to other countries that have existing LUP regulations has shown developments and progress as the world strives to identify a best practice. Learning from the modifications and results of other countries LUP policies will only benefit a policy implemented in the U.S. Comparisons between approaches and countries has identified the key elements and issues that a LUP policy must address.

Lastly, analysis of current or lack of current U.S. policy regarding LUP is required. Finding the level or levels of government and/or parties of interest to include in the LUP decision-making process is unique to the U.S. and can only be done with analysis of the U.S. governmental system. Upon completion of identifying the aspects of a LUP best practice, combining these aspects into a policy that could work for the U.S. government is perhaps the biggest hurdle. Suggesting a policy that is flexible enough to work for all fifty states and all of their local communities, and requires sufficient backbone for enforcement and effectiveness will be the key contribution of this work.

3. CASE STUDIES

The incidents briefly outlined below are heavily scrutinized in the history of the chemical industry and the dangerous operations associated with it. The chemical industry is relatively one of the safest industries, however incidents such as these are the reason for the negative connotation that many civilians associate with it. For example, the name Bhopal has become synonymous with industrial tragedy because of a toxic gas leak. The extensive destruction and devastation, in part due to poor LUP, of a few chemical incidents has become known worldwide. Although the chemical industry has one of the lowest incident rates among industries, its major incidents are often catastrophic, resulting in the negative association. Proper LUP, in the Bhopal case and other cases, could have prevented or greatly minimized the impact to the local communities that were sustained. The name Bhopal and the communities in which each of these other incidents occurred will forever be stained by these tragedies and the catastrophic effects. It is up to communities and governments around the world to prevent the calamitous effects of future chemical industrial incidents with the assistance of adequate LUP.

3.1 GAS LEAK IN BHOPAL, INDIA

During the early hours of December 3, 1984, more than 40 tons of toxic methyl isocyanate gas leaked from the Union Carbide Corporation's (UCC) chemical plant in

Bhopal, India and swept through the uninformed surrounding population of almost a million people. Around 1:00 A.M. the pressure, built up within one of the storage tanks, at the plant gave way due to the exothermic reaction between water and the pesticide chemical formulation intermediate methyl isocyanate (MIC), which resulted in the release of a large plume of toxic gas. Within the following hours crisis ensued as humans, livestock and pets perished on the streets of Bhopal. Local hospitals and clinics overflowed with injured victims while the turmoil was further compounded by a lack of knowledge of plant operations and the nature and effects of the toxic gas that had swept through the city. The short and long-term effects of the disaster remain unmatched as the gas leak immediately killed at least 3,700 while exposing over 500,000 more. Some estimates on the number of fatalities are as high as 10,000 with as many as 20,000 more premature deaths reported due to the health effects of the toxic gas release over the following two decades [3]. The lasting effects of the gas and the disregard for process safety at the UCC pesticide plant shadow the name Bhopal and the chemical industry. The number of LUP and process safety factors contributing to the incident is alarming, and has served as a costly incident for lessons learned.

UCC had been sought after to build a plant in India, for pesticide production, in an effort by the Indian government to encourage foreign company investments in local industry in the 1970s. The location for the plant had been chosen in Bhopal for its centralized location and ease of access to existing transport infrastructure within the country. The precise location of the plant within the city had been reserved for light industrial and commercial use, but at the time of the incident the plant was far from being classified as light industrial and commercial use [4]. Originally, the plant was to import the hazardous MIC in small quantities, but for economic reasons, the plant adopted the complete process of the pesticide formulation within the facility. The new operations exponentially increased the hazards within the plant and the risk to the surrounding community [5]. The process modifications made to the plant brought about increased risk at the justification of saving money. Three key safety systems were either not in use, not properly designed, or turned off on the morning of the incident. The refrigeration system, originally designed to cool the storage tanks in the case of a run-a-way reaction, was shut down two years earlier and had since had its Freon removed to be used at another facility. The flare tower at the plant, used to burn off the MIC, had had a connection pipe removed and was therefore useless. A vent gas scrubber was also turned off on the morning of the incident. Both the vent gas scrubber and the flare tower were insufficiently designed to handle the magnitude of the leak produced on December 3 1984.

The relation of Bhopal to LUP is ubiquitous. Process safety deficiencies at the UCC plant led to the incident, but the clear lack of LUP and community awareness resulted in the magnitude of the incident. The shantytowns surrounding the plant and the population of Bhopal increased and encroached closer to the plant through the years as it provided jobs to the community, a problem that could have been mitigated with LUP. Additionally, the specific site for the plant was not zoned to allow hazardous operations, yet UCC was allowed to build and modify their plant to become a facility with a hazardous process and storage of a highly toxic intermediate. Lastly, there is the issue of the community not being aware of the potential of a gas leak and not knowing how to respond. Hospitals did not know what to treat or how to treat an exposure from the plant.

The utilization of a LUP policy could have significantly reduced the number of fatalities and those exposed to the toxic gas by limiting or preventing communities to grow next to the plant or vice versa. The absence of LUP use in India and UCC at the time dramatically changed the chemical process safety industry. The events in Bhopal exposed that expanding industrialization without simultaneous advancements in safety regulations can have catastrophic consequences [6].

3.2 AZF FERTILIZER FACTORY, FRANCE

On September 21, 2001, nearly 400 tons of off-specification ammonium nitrate (AN) exploded crippling the city of Toulouse, France. Located within the city, the AZF (Azote de France) fertilizer factory exploded with the power of 20-40 tons of TNT, leaving a 65 m x 54 m x 7 m crater [7]. The AN explosion killed 31, injured up to 10,000, caused nearly 3 billion dollars in damage and resulted in new legislation for LUP. The tragic incident exposed the deficiencies of risk management, forcibility to remove inhabitants living in close proximity to hazardous facilities, lack of communication with communities, and urban pressure causing encroachment of inhabitants to the hazardous facilities in their current LUP policy.

The economic and urban environment of Toulouse, France grew greatly over the decade preceding the explosion, as the two struggled to find a balance in LUP. Dating back to the 1800s, in France, there is evidence of LUP and the realization that risks are prevalent to communities because of hazardous facilities located nearby. Explosions in 1781, 1816 and 1840 caused nine deaths and damage to the surrounding areas and pressured the city council to take action regarding the cities' LUP [8]. As a result, the industrial sector of the city was moved to the outskirts of town as the urban area continued to expand. The urban population grew exponentially over the years following World War I and World War II as the manufacturing and chemical industry, within the city, provided economic growth and jobs. The urban development overtook the areas surrounding the hazardous sites despite a warning from the Director of the explosive factory [8]. The city was well aware of the hazards, and better LUP should have been taken into account. Unfortunately, there was a lack of action due primarily to the fact that urban development took precedence over safety. The years preceding the AN explosion contained discussion regarding safety distances, urban development, safety studies, and potential plans of action. However, the rapid pressurization for urban development from their current urban situation attributed to unsuitable application of strict LUP around the hazardous facilities [8]. A case for positive use of LUP can be made between 1989 and 2001 in Toulouse, even though more could have been done. The PIG (Plan d'Intérêt Général) perimeter, which is based on the distance of a lethal concentration for 50% of people exposed, was calculated for the AZF fertilizer factory. Within the PIG perimeter, developmental restrictions were set that prevented further urban development in the years following 1989. However, the development of the PIG perimeter and non-authorized housing developments in the years preceding the explosion in 2001 only made a slight difference considering that the LUP had no force to remove or mitigate the risk for developments established prior to 1989 [8].

The AN explosion in Toulouse is a good case of insufficient LUP. The explosion that riddled through the city shattered windows, doors and shops and left over 500 houses uninhabitable [9]. The destruction to the community was vast even with their LUP efforts. The city was well aware of the potential consequences in relation to inadequate LUP and attempted to mitigate this risk. There had been discussion and limited action to mitigate the risk to the areas surrounding the AZF fertilizer factory, nevertheless; significantly, more action was needed to protect the community and its victims.

3.3 EXPLOSION IN WEST, TEXAS

The West Fertilizer Company (WFC) located in West, Texas was the home of an ammonium nitrate (AN) explosion on April 17, 2013. The blast killed 15 and injured up to 300 more. It destroyed personal homes, an apartment complex, a nursing home and multiple schools located within the explosion radius of the blast. This incident highlighted the lack of effective LUP practice in the U.S. and should serve as a learning lesson for future LUP policy and implementation. Questions concerning the regulation of LUP in the U.S. have been raised since the incident, yet little progress has been made in any type of action or legislation.

The WFC was founded in 1962 as a chemical supplier to farmers. When the facility was first founded in 1962, it was safely on the outskirts of town. At the time, the city of West also lacked zoning regulations, although such regulations would have been of little help giving that the WFC was located outside the city limits [10, 11]. For years, the community experienced substantial growth and expansion, growing within dangerous proximity of the ammonium nitrate storage facility, so much so that the community hardly realized the hazard they were approaching. The fact that the WFC did not manufacture chemicals but was rather only a large storage site; it was not seen as a major risk to the community. In 1985, a little more than 20 years after the WFC was built, the West Independent School District (WISD) built an intermediate school only 552 feet from the WFC [10]. A few years later in 2000, the WISD constructed a second school within the blast radius of the facility. In all, the WISD had four schools that were damaged by the explosion, two existing prior to completion of the WFC and the closest two schools built after the opening of the WFC as seen in Table 1. Private residences were also permitted within the blast radius of the explosion calling for additional destruction to the community. Additional absence of LUP is visible in the construction of a nursing home and apartment complex in close proximity to the WFC after the WFC had already been in business for several years.

Table 1 - West Land Developments around WFC [10]

Structure	Year Constructed	Distance to Explosion Center (feet)
WFC	1962	------
West Middle School	1923	2,000
West Elementary School	early 1960s - 1966	4,867
West Independent School	1985	552
West High School	2000	1,157
West Rest Haven Nursing Home	1967	629
West Terrace Apartment Complex	1979	454
Park/basketball court	N/A	249

On the evening of the explosion a fire broke out around 7:29 p.m. within the storage facility causing an explosion with the energy equivalent of approximately 12.5 tons of TNT [12]. Approximately 22 minutes later a large explosion riddled through the city as the stored AN exploded and took the lives of 15, including 12 first responders whom were responding to the initial fire [12, 13]. The lack of community awareness and preparedness for such an event at the WFC in addition to the lack of information regarding the stored materials, quantifies and associated hazards attributed to the loss of the 12 first responders. Even more troubling is that in May of 2016 the Bureau of Alcohol, Tobacco, Firearms and Explosives ruled the initial fire at the WFC was intentionally set [13].

Consequences of the explosion still exist in the city of West today. Of the 700 houses located in the city, half of them were impacted by the incident; the explosion also completely destroyed the nursing home and apartment complex [10]. However, the city was very fortunate with the timing of the explosion. Luckily, the explosion occurred in the evening when there were no students or faculty present at the schools. The WISD suffered extensive damage to the intermediate school, high school and middle school and minor damage to the elementary school. Two schools and the majority of a third ended up being demolished due to the irreparable damage sustained by the explosion [10]. The consequences of the incident would have been noted as much worse had the explosion occurred while school was in session.

The explosion in West, Texas will leave an everlasting mark on the community, the State of Texas and the U.S. It serves as a perfect example of the severe consequences that can ensue with insufficient or simply a lack of LUP.

3.4 EXPLOSION IN TIANJIN, CHINA

Ruihai International Logistics Co., Ltd. was a hazardous material warehouse located in the northeastern port city of Tianjin, China. The deadly combination of illegally storing large quantities of hazardous materials, corruption, inadequate LUP and management deficiencies resulted in multiple explosions, casualties and massive amounts of destruction.

Shortly before 11:00 pm on the night of August 12, 2015, Tianjin firefighters received word of a small fire inside the storage facility. As they arrived on site around 11:10 pm, the fire had expanded to several large storage containers. The firefighter's ability to fight the fire was severely hampered by stacked storage containers limiting their access to the fire. Some containers were illegally stacked up to five high. At 11:30 pm the first explosion occurred, followed by a larger second blast about 30 seconds later. Fires and small explosions continued for almost two days following the initial explosions. It is estimated that 800 tons of ammonium nitrate was responsible for the second blast that had an estimated equivalent energy of 430 tons of TNT [14].

One hundred and sixty five people, mostly first responders, lost their lives in the tragic explosions and another 233 were admitted to the hospital [15, 16]. The blast was lethal out to 300-meters and created a shock wave that damaged the windows of 17,000 households [16]. The full extent of the destruction is displayed in Table 2.

Table 2 - Tianjin Explosion Incident Losses [14]

Loss Categories	No.
Deaths	165
Injuries	798
Destroyed buildings	304
Destroyed vehicles	12,428
Destroyed containers	7,533
Total direct economic losses	6.866 (Billion yuan) about 1 billion American dollars

Contributing factors to the incident include illegal storage quantities of hazardous materials, improper storage of flammable substances next to explosive substances, unsafe handling procedures and inadequate LUP. City officials were aware that the warehouse was not in compliance with safety distances, yet they approved its operations anyways [16]. A clear disregard for LUP and public safety on the part of the city officials. Thankfully, the explosion occurred late at night when neighboring businesses were closed. Otherwise, the consequences of the incident could have been much worse. China has vowed to punish an excess of 100 officials that were involved in the illegal storage of hazardous materials. Following the incident, China has been working towards refining their LUP and ensuring that governmental and chemical industry officials are held accountable. Phasing-out and expropriation have been discussed as possible options to mitigate future LUP risks.

4. PROCESS OF APPLYING LUP

The diverse environments in which LUP is applied in has resulted in various LUP policies. Countries have implemented polices that are best for their economic, structural, technical and political environments. Nevertheless, the process of applying LUP can be broken down into three main steps:

1. Scenario identification and assessment method
2. Defining acceptable criteria
3. Zoning & Risk Reduction Techniques

In order for adequate LUP to be applied, there must first be proper scenario identification and corresponding assessments. Implementing LUP to less than worst-case scenarios can lead to inadequate planning and protection to the area surrounding a hazardous facility. In addition to policies regarding the selection of credible and conceivable scenarios, LUP shall also address the method of choice for evaluations. Whether using consequence or risk assessments to inform the LUP decision-making process, the preferred method process should be detailed in the regulations. The second step of applying LUP is defining acceptable criteria for threshold values, separation distances, consequences and risk levels. These criteria can be defined in regulations or provided in the form of suggested values in guidelines. The latter is used for a more decentralized approach, leaving the decision up to local authorities, planning agencies, or states. The final step of LUP is applying risk reduction techniques and zoning requirements. Risk reduction can be in the form of increased community awareness and preparedness, emergency planning, inherently safer design, safety precautions and measures on site. These techniques are applied to various extents by the different countries. For example, some focus heavily on inherently safer design at hazardous facilities, seeking to employ the state of the art safety technology irrelevant of cost, while other countries employ a cost-benefit approach to the use of safety technology. Within zoning, LUP regulations can include the number of zones, developmental restrictions for each zone, permitting procedures, phasing-out and expropriation. Step 3 in the process of applying LUP is the action taken in response to LUP situations. Whether it is using risk reduction techniques or zoning requirements the effectiveness of the actions is largely responsible for the level of success of LUP. Approaches, methodologies and acceptable criteria differ between countries but they all aim to mitigate the effects to the areas surrounding hazardous facilities. Insignificant differences have been found between the uses of the various approaches and methodologies, pointing to the critical step of LUP being step 3.

5. THE LIMITATIONS OF LUP

There are numerous factors and questions that must be addressed before an effective LUP policy can be implemented in the United States. LUP is a significantly more complex issue than it appears on the surface. The assortment of situations in which LUP is applied makes a single solution or even a series of simple solutions impractical. The practicality of placing a buffer zone around every hazardous facility is currently illogical. In addition, a best practice for implementing and enforcing LUP is exclusive to each country due to the distinct economic, political, developmental, and governmental climates of each.

Separation zones are established with varying distances from the location of the hazardous facility as an implementation of LUP restrictions. Within each approach and each country, threshold level values (TLVs) or risk criteria are established to distinguish between hazardous separations zones such as first deaths, first irreversible effects, minor injuries, etc. France, for example, sets up two separate zones surrounding hazardous facilities; the first is the distance in which the first occurrence of death is likely to appear, the larger second zone is at the onset of an irreversible effects to a citizen. Within the first zone, urban developments of sensitive inhabitants are prohibited such as hospitals, schools and nursing homes. Within the outer zone, urban developments that significantly increase the population or residential housing are prohibited. The criteria for the zones used, the number of zones, the land use restrictions within each zone and the criteria to establish them varies by methodology, approach and country. The application of the separation distances for LUP is generally the same for all three approaches; the difference arises in the means used to arrive at the separation distances. Defining separation zones is a significant portion of LUP, but proving the effectiveness and enforcing them is the challenge. What is safe enough and how can it be verified? Are the separation distances large enough to prevent fatalities, yet small enough that they are enforceable and do not embargo large amounts of valuable land within cities.

The solution to LUP in the United States will have to be flexible and thorough, establish minimum safe operation distances and account for both growth of facility and a community around it. Interest of different levels and departments of government, agencies, developers, landowners, local residents and other members of the public all have part in LUP and should be considered in the decision making process. Decisions at the local level are employment opportunities, benefits to the community from the operations of the facility, and future growth of the city [17]. A new or expanding facility within a community can bring about economic profitability, but depending on its location, at what cost to risk? Listed below are the questions that should be considered to create successful implementation of LUP:

- If LUP is community driven, how can it incorporate big government or have a federal regulation and make it work?
- What is everything that needs to be included for an effective LUP policy?
- What level of government should oversee the issue?
- How to address existing facilities within communities?
- How to handle future growth around a facility?

- What is safe enough? Level of acceptable risk [17]?
- How can the safety distances be verified?
- What methodology/approach to use?

The answers to these questions are complicated by the interest of the various groups that could be impacted by a LUP policy or decision. What one community or state prefers may not work for their neighbors. Flexibility will have to be incorporated into a LUP policy to account for the different economic, structural, political, technical, and other differences between states and even communities within states [18]. Every situation is different, and while no two solutions will be the same, it is clear that something must be implemented. Accidents will happen, and incidents will occur; the catastrophic consequences of them destroying communities and taking lives are unacceptable and should be addressed. Answering these questions thoroughly is the first step in the process of implementing a LUP policy in the U.S.

6. THREE APPROACHES TO LUP

Three main approaches to LUP have been established: generic safety distances (GSD), a consequence based approach (CBA) and a risk based approach (RBA). All three approaches are currently in use to at least some degree. The extent that each is being used has changed with time and advancements in the industry and LUP. Each approach presents its own set of pros and cons, and each country is to pick what works best for them. Some countries that implemented a LUP policy have since adapted the original approach in response to an incident, changes in industry, or advancements in risk analysis. Some have even changed approaches completely in response to incidents, changes in industry, or changes in the landscape of the country all in an effort to continually improve their LUP policy. Other countries have implemented a combination of two approaches or have at least taken parts of one approach to incorporate into their LUP policy. Advancements in industry and risk management/calculation affect the effectiveness of each particular approach, and changes are required to keep up with best practices. Although these three approaches are significantly different in their methodologies, they all aim to mitigate the risk to communities by the use of LUP.

6.1 GENERIC SAFETY DISTANCES APPROACH (GSD)

The generic safety distances approach, the simplest of the three, does not take into accounts the consequences or risks of major hazards. Instead, safety distances are based on the hazardous substances present, their quantities and the nature of the facility operations [18]. The pros and cons of this approach are summarized in Table 3.

The main benefit of this approach is the simplicity, resulting in a quick, time saving methodology to apply LUP. With safety distances determined based on effects and not on risk or consequences, less analyses and calculations are required, saving time and resources. Another benefit of this simplistic approach is the elimination of the uncertain variable of frequency and corresponding variance in assessed risk. There is great difficulty in assigning and calculating the probabilities of high consequence, low probability events that have led to LUP catastrophes. The large uncertainties in risk analysis regarding such events can greatly affect the results of LUP and lead to inefficient or ill-advised land use. As industry and risk analysis advances our ability to accurately define risk levels within the chemical industry, it will give more credibility to a risk based LUP policy. For now, though, this is an advantage of the generic safety distances approach.

The GSD approach seeks to ensure essentially zero harm to the community, however, this leads to large areas of land being embargoed, an obvious con for urban development and economics of the community [19]. Additionally, the generalized nature of this approach does not take into account safety measures, safety features designed into the facility or the specifics of the facility operations. Therefore, a facility with very poor safety conditions, features and design can have the same safety distances as a new facility with the most modern safety designs, conditions and a significantly lower potential for an incident. This can lead to a greater area of land being embargoed than necessary with a safe, modern facility or less land being embargoed surrounding a high-risk facility due to poor safety conditions.

Table 3 - Pros & Cons of GSD Approach

Generic Safety Distances	
Pros	**Cons**
Simplest approach	Significant areas of land can be embargoed [19]
Does not include the uncertain variable of frequency or large variance in calculated risk	Safety characteristics, measures & particulates of the facility are not accounted for [18]
Goal of zero harm to community	No account for scenario likelihood

Industry is continually learning and gathering more information regarding the probabilities of high risk, low probability incidents that have caused catastrophic incidents. As industries' knowledge advances, the generic safety distances approach becomes less ideal for communities looking to maximize the economic availability of the lands surrounding hazardous facilities. Fortunately, this approach is certainly better than nothing is and has been a positive starting point for several countries.

6.2 CONSEQUENCES BASED APPROACH (CBA)

In the consequences based approach (CBA) only the severity of an incident is accounted for, the likelihood of occurrence and corresponding risk calculation are ignored for LUP purposes. The CBA is similar to a worst-case scenario analysis in that the consequences of one scenario or incident are taken into account for defining the separation distances. The belief is that the separation distances of a worst-case scenario will sufficiently protect against all other less than worst-case scenarios. Some countries utilize a list of reference scenarios that are based on past incidents or foreseeable consequences of facilities in order to determine the worst-case scenario that will be used. A con of the CBA is that it is often difficult to identify the worst conceivable scenario [18, 19]. Improper determination of the worst-case scenario can lead to improper land use and inappropriate allotment of risk exposure to the surrounding community. Table 4 summarizes the pros and cons of the approach.

Much like the GSD approach, the CBA does not use a risk variable in its calculation of separation distances, eliminating the uncertain variable of frequency and large variance in calculated risk [19]. While this is a positive of the approach in itself, it may consequently lead to a larger area of land being embargoed than desired. Another unfavorable characteristic is the challenge of establishing opportune threshold levels for undesired effects and industries [19]. As mentioned previously with the calculation of risk, uncertainty and large variance is a characteristic in evaluation of hazardous facilities and industries. The low probability incidents and limited historical data limit the validation of risk calculations, separation zones and threshold levels.

Table 4 - Pros & Cons of CBA Approach

Consequence Based Approach	
Pros	**Cons**
Less time consuming than risk based approach	Tends toward significant areas of land being embargoed
Does not include the uncertain variable of frequency or large variance in calculated risk	Difficult to determine suitable threshold levels for risk effects
	No account for scenario likelihood
	Can be difficult to determine worst case scenario

In terms of time, money and complexity, the CBA falls in the middle of the three approaches. It is more time consuming, expensive and complex than the GSD, but less than the risk based approach (RBA). The key attributes of the approach include the worst case scenario is used, threshold values are set for undesired effects and the likelihood of incidents is not accounted for. Some countries have shifted to utilize more of a CBA, as others have shifted away from the CBA. An argument can be made for the effectiveness of this approach and it is perhaps the most widely utilized approach.

6.3 RISK BASED APPROACH (RBA)

The intention of the risk-based approach (RBA) is to incorporate the consequences of a potential incident and the frequency or likelihood of that event. The methods used are believed to be more complete and comprehensive because of the incorporation of the variable of frequency; after all, risk is equal to frequency multiplied by the consequences. Some believe that incorporation of risk into the calculations for LUP makes it the most extensive method justified for the major incidents evaluated for LUP [19]. However, this is also the major drawback of this approach. The primary objection for the RBA has been the inclusion of frequency and its corresponding uncertainty related to low probability, high consequence incidents. The two approaches mentioned previously do not include the large uncertainty of a frequency variable, and consequently, have no frequency variable listed as a positive aspect of the approaches. Therefore, inclusion of frequency in LUP is both a positive and a negative attribute dependent upon the LUP approach. As advancements are made in risk calculations and the accuracy for the likelihood for low probability, high consequence events in the chemical industry increases, the more positive inclusion of a frequency variable becomes for LUP purposes. Table 5 summarizes the pros and cons of this approach.

A third positive of this approach is the ability to measure individual and societal risk to incorporate them into the risk zones [19]. Individual risk is the annual risk of death or serious injury defined by the probability as a result of an incident, and societal risk is often referred to as the relationship between frequency and consequences expressed on an F-N curve [20]. This approach generally incorporates three risk regions (unacceptable, affordable, and acceptable) into the LUP evaluations. Each region should have clearly defined criteria levels, mitigation and appropriate actions to take.

Table 5 - Pros & Cons of RBA Approach

Risk Based Approach	
Pros	**Cons**
Most comprehensive method	Uncertainty related to the frequency of low probability, high consequence events
Individual and societal risk are accounted for	More time consuming, complicated and expensive than other two approaches
Accounts for frequency of events	

Arguments can be made for or against any of the three approaches, but the RBA garners the most discussion. There is considerable speculation concerning the incorporation of a frequency variable. The challenge of accurately assigning frequency values to low probability, high consequence events significantly affects the risk levels and LUP regulations. On one hand, it makes the calculations more comprehensive and justified for major accident hazards and, on the other hand, it adds a larger value of uncertainty.

6.4 APPROACH IMPLEMENTATION

The descriptions and tables above show that positive attributes for one approach are often negative attributes for one or both of the other approaches. This is certainly the case with the variable of frequency; it can be a negative aspect due to its uncertainty or a positive aspect for its all-inclusive nature. As industry continues to advance in risk based analysis methods, the RBA will become more and more effective. These raises the questions of when improvements in risk analysis will become adequate, and how can it be proven adequate. Regardless, LUP is dynamic and the RBA will not be the best practice for every country.

The strict interpretation of each approach was discussed above; furthermore, implementation of a single approach can be limiting to its applicability, especially in a highly developed country like the U.S. were land is at a premium. In industry and throughout the world it is more common to see implementation of multiple approaches or adaptation of two approaches by a single country to best fit their economic, political, structural and governmental climate as seen in Table 6. There is flexibility and numerous methodologies that can be used to obtain similar results with each approach and an argument can be made for each approach as best practice depending on the situation. A comparison of the effectiveness of LUP policies between countries is almost impossible considering the rarity of incidents and the numerous methodologies used to obtain separation distances. With so many factors, components, circumstances and different interest groups every LUP policy is expected to be different. The separation distances calculated with one policy will certainly differ from another but the critical aspect of the policy will be in the mitigation, handling and enforcement of the separation distances. Therefore, the effectiveness of a policy enacted in the U.S. will notably rely upon its ability to flexibly and effectively mitigate risk to the community.

Table 6 - Overview of Current LUP Approaches (Adapted from [21])

Country	Generic safety distances	Consequence based approach	Risk based approach
Austria	X		
Belgium		X (Walloon)	X (Flemish)
Canada			X
Denmark			X
Finland		X	
France		Prior to 2003	After 2003
Germany	X	X	
Hong Kong			X
Italy		X	
Luxembourg		X	
The Netherlands			X
Spain		X	
Sweden	X	X	
Switzerland			X
The United Kingdom		X	X
United States		X	

7. EUROPEAN UNION (EU)

The European Union (EU) is a political and economic union between 28 European countries referred to as the Member States. Initially created in 1958, to promote economic cooperation, it has grown to incorporate much more. Legislation promulgated by the EU is the equivalent of a national law; it is the responsibility of the Member States to implement EU legislation into a national law and adequately enforce it. The Seveso Directives are a series of three directives and an amendment that combine to form the main EU legislation for regulating the control of major accident hazards involving dangerous substances as seen in Figure 1. Seveso I Directive (82/501/EEC) was enacted in 1982 to promulgate the requirements for emergency planning, informing the public, and the requirement of operators and owners to maintain a list of hazardous substances. Seveso I is very similar to the United States Emergency Planning and Right to Know Act of 1986. Seveso II Directive (96/82/EC) addresses major accident prevention and separation distances, similar to the United States Clear Air Amendments Act of 1990. In 2003, the EU enacted an amendment to Seveso II that created a working group to increase uniformity among the Member States for implementation of major accident planning and separation distances [22]. This working group set up by the EU provides guidance to the LUP authorities of each of the Member States and runs the incident database for the EU. The amendment also requires owners and operators to verify that offsite risk is acceptable, adding emphasis to proper LUP. Most recently, in 2012, the EU implemented Seveso III Directive (2012/18/EU). Seveso III strengthened

LUP policy by placing additional emphasis on emergency planning, providing information to the public, strengthening inspection requirements, and incorporating the Globally Harmonized System(GHS) of substance classification [22].

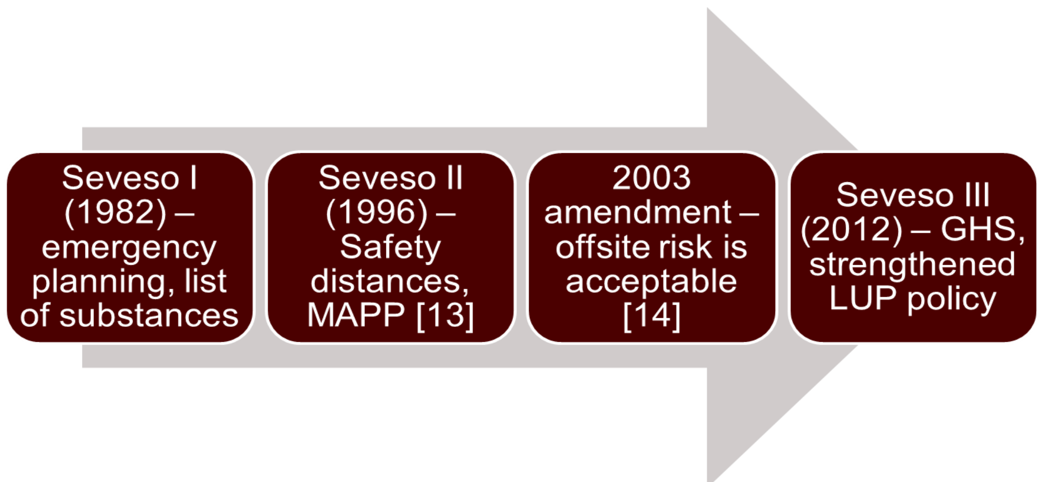

Figure 1 - EU Seveso Directives

The Seveso Directives set out by the EU require the Member States to implement a LUP policy but do not specify the methodology or approach to be used. They require that a LUP policy addresses the aspects of establishing and maintaining adequate separation distances, the need of additional safety measures in existing facilities and preventing major incidents by mitigating the consequences for the siting of new, existing, as well as the modification of existing facilities [17]. At the national level: criteria are defined for the level of acceptable consequences or risk with separation distances, restrictions are set for developments within those separation distances, and guidance is promulgated for future LUP if those conditions are not met. The local level, however, often has the decision-making rights in the LUP decision-making process.

8. GERMANY

Germany has taken a decentralized approach to LUP regulations with their system of national, state and local governments. The national and state governments provide the framework for LUP policy while local governments establish land use plans. At the national level, the Spatial Planning Act provides guidance for the planning process and defines the basic principles for LUP in Germany [22, 23]. In accordance with the requirements of Article 12 of the Seveso II Directive, the methods of LUP are defined in the pollution protection law as well as the urban planning law [24]. Additional regulations at the national level include the Federal Building Code (BauGB) and the Federal Land Use Ordinance (BauNVO), which together recognize the use of appropriate separation distances to minimize the effects of major incidents. Regulations not directly addressed in the regulations above are decentralized to the states and local levels of government. The criteria for acceptable safety distances/consequences are determined by each individual state; yet, the local levels of government have the ability to implement their own.

Germany has taken a different perspective on the approach and methodology used for LUP than most other countries. Germans have placed a significant emphasis on utilizing state of the art safety technology in an effort to minimize the effects of an incident. No reference to cost-benefit is made in the application of safety measures to minimize the effects of an incident. Safety measures and technology on site are a priority for the operations of hazardous chemical facilities, and the extent of their implementation are taken into account in the LUP process. Germany is also one of the few countries who use GSD for LUP. GSD based upon historical data and expert judgment from operating experience has historically been used. Noteworthy, Germany has transitioned to a combination of GSD and a CBA based upon the presence of noxious characteristics [18]. Generic safety distances are used when a facility does not require a detailed hazard assessment due to lack of noxious characteristics or in the case of existing operations involving explosives and fertilizers (AN). In these cases, separation distances are applied based upon the substance present and its quantity. For new developments near existing hazardous facilities (a case – by – case basis) or for the presence of noxious characteristics (worst conceivable scenario) a consequence-based approach is utilized. In the presence of noxious characteristics, separation distances are distributed amongst four classes, as displayed in Figure 2, based upon quantity and end-point determination for thermal radiation, explosive overpressures and toxic concentration [24]. Guidance for recommended separation distances were originally defined in the guidance document “SFK/TAA-GS-1”, but have recently been updated in “KAS-18.K” [25]. Germany has been reluctant to use QRA for LUP due to the uncertainty of probabilities assigned to major incidents in the industry and the resultant variance in the results of a QRA.

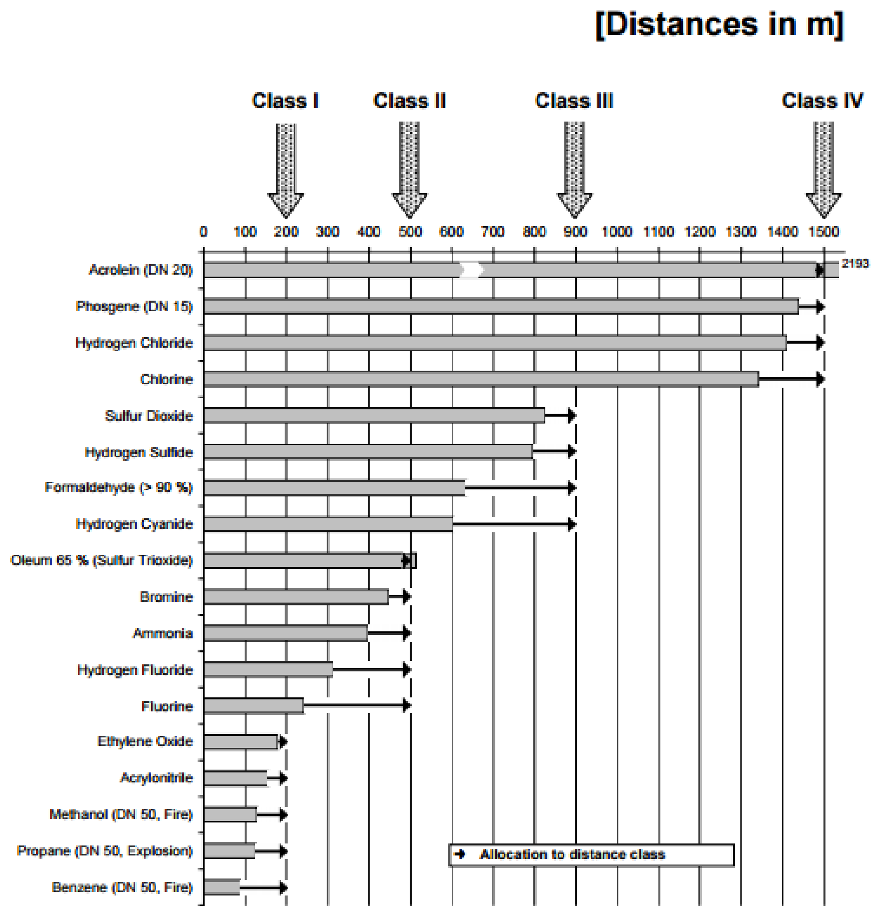

Figure 2 - Generic Safety Distances in Germany [25]

The goal of LUP in Germany is for no serious hazard to reach the public population surrounding the hazardous facility with emphasis placed on the application of state of the art safety technology. Recommended safety distances seek to prevent no harm to the public, but they are only recommendations and not mandatory to be applied by the local governments in charge of LUP. Germany is a good example of required flexibility and reluctance to apply risk assessments in the application of LUP. By utilizing GSD and a CBA, they have simplified the application of LUP and have made the competent authority the party with the most interest, the local government.

9. FRANCE

In 2001, an explosion of ammonium nitrate stored at a fertilizer factory in Toulouse, France occurred. Unfortunately, for France and the community of Toulouse, urban development had taken precedence over safety and proper LUP. The impact of the explosion in conjunction with devastating flooding the following year sparked new regulations and advancements in LUP and risk analysis.

Prior to 2003, France solely used a CBA for the evaluation of LUP based upon the identification of the worst-case scenario without regard for incident probabilities. A list of reference scenarios such as fire, explosion, or BLEVE (boiling liquid expanding vapor explosion) were used to help identify the worst-case scenario. Owners/operators in agreement with authorities were required to evaluate the consequences of the various reference scenarios and demonstrate that adequate measures to minimize each ones consequences had been taken [18]. The list of reference scenarios was not all-inclusive; owners/operators had the ability to evaluate additional incident scenarios, and/or authorities could require additional scenarios to be evaluated. Upon completion of the consequence analyses on the required scenarios, the worst-case was further evaluated for LUP purposes. Threshold values were then utilized for the determination of the two circular danger zones that France LUP requires.

After 2003, France called for the investigation and assessment of probabilities for all possible scenarios [9]. By incorporating a probability assessment, thereby making it a RBA, they felt as though it would be a better representation of potential incidents.

However, France did not switch completely to a RBA. The new regulation allows for the use of probability assessments to help inform the decision-making process and to better prepare for potential incidents, yet, LUP zones are still primarily based on the consequences of an incident. The new regulation aims to improve three critical areas of LUP [9]:

- Addition of probability assessment to complement existing analysis
- Standardization of risk analysis procedures
- Ability to take action to remove existing establishments and to control future growth surrounding hazardous facilities

To accomplish these three goals, the new regulation created technological risk prevention plans (PPRT) to consider the types of risks, their gravity, and their probability. The basic goal in France was to harmonize risk analyses procedures and LUP evaluations.

Tolerability criterion and LUP procedures in France follow a very systematic process and are well documented in the *Code de l'Urbanisme*. Article 110 within the code addresses the public's health and safety in regards to LUP and states that prevention of industrial risks shall be taken into account in the local planning process. The French Ministry of the Environment has established a national matrix for risk acceptability based upon gravity and probability levels. Gravity is defined as a combination of the intensity of the effects and the number of people in the area and is divided into five levels as seen in Table 7 [9].

Table 7 - Gravity Levels in France [9]

	5% lethal effects	1% lethal effects	Irreversible effects
Disastrous	>10	>100	>1000
Catastrophic	1–10	10–100	100–1000
Major	1	1–10	10–100
Serious	0	1	1–10
Moderate	0	0	<1

Probability levels are also divided into five levels resulting in a 5 by 5 matrix used to determine the acceptability of risk surround hazardous facilities as seen in Table 8. No new facilities, modification of existing facilities, or the construction of new establishments near existing facilities is allowed if a risk exists in the red/NO region. The NO/MMR2 region is also off-limits for the construction of a new facility. Proposals for new developments must not result in five or more risks within the orange/MMR2 region of the risk matrix in order to be approved. The yellow/MMR1 region means that facilities must utilize risk reduction measures to be approved [9]. Furthermore, two zones or perimeters are established based upon risk levels. Within the outer zone, new establishments and modifications to existing ones can be prohibited and are evaluated on a case-by-case basis by the state representative at the local level in conjunction with the local authorities. Establishments within the inner zone are subject to expropriation [9, 23].

Table 8 - France's National Risk Acceptability Matrix [9]

GRAVITY	PROBABILITY E	D	C	B	A
Disastrous	NO/MMR2	NO	NO	NO	NO
Catastrophic	MMR1	MMR2	NO	NO	NO
Major	MMR1	MMR1	MMR2	NO	NO
Serious			MMR1	MMR2	NO
Moderate					MMR1

The PPRT take the procedures a step farther in risk evaluations used for LUP decisions. The risks previously characterized in the national risk matrix are combined to give overall risk levels at each location surrounding a hazardous facility using Table 9. The result is a new map with zoning requirements that are evaluated by the state, regulatory bodies, operators, and locals before being approved as an outcome of the PPRT. The restrictions are summarized in Table 10.

Table 9 - France's Zoning Levels [23]

Maximum intensity of the toxic, thermal or overpressure effects on humans at a given point	Very serious *Significant lethal*			Serious *Lethal*			Significant *Irreversible*			Indirect
Cumulative probability distribution of dangerous phenomena at a given point	>D	5E to D	<5E	>D	5E to D	<5E	>D	5E to D	<5E	All
"Aléa" level	VH+	VH	H+		H	M+		M	Low	
Zoning	Dark red		Light red			Dark blue			Light blue	

Table 10 - France's Zoning Principals [26]

Regulated zones	Future land-use planning and construction measures	Possible real-estate measures
Dark red	Ban on new construction	Expropriation Relinquishment
Light red	Ban on new construction but possibility to extend existing industrial buildings if they are protected	Relinquishment
Dark blue	New construction possible depending on limitations on use or protection measures	
Light blue	New construction possible depending on minor limitations	

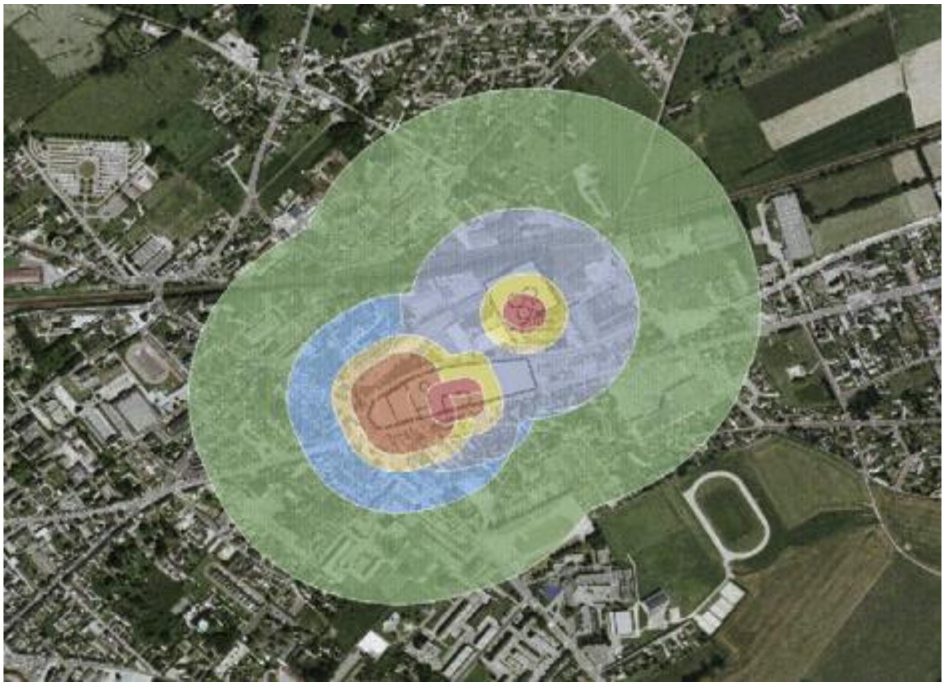

Figure 3 - France's Risk Map [26]

France is noted for its inclusive and refined LUP process; however, it has come at the cost of being time consuming and in response to the Toulouse incident. France felt that their previous regulations could be improved with a better-defined process and additional flexibility incorporated into the analyses used for LUP purposes. The new regulation in 2003 did not attempt to change the main principles of the initial LUP regulation, but, it provides a more sound framework for LUP, which allows the incorporation of a RBA [27]. France reasoned that the addition of frequencies and risk analysis can take into account risk reduction measures better, leading to the evaluation of scenarios that are better than worst-case [28]. France improved their LUP by adding flexibility into their assessment methods, harmonizing the assessment approach and by addressing future growth and existing establishments surrounding hazardous facilities.

10. UNITED KINGDOM (UK)

The UK has a well-known safety institution in the Health & Safety Executive (HSE), which oversees the health and safety of the country by implementing and controlling a number of acts and regulations. In response to the Seveso Directives, the HSE is in charge of implementation of the Planning (Hazardous Substances) Act of 1990, Planning (Hazardous Substances) Regulations of 1992 and Control of Major Accidents Hazards (COMAH). The HSE in combination with the Environmental Agency for England and Wales and the Scottish Environmental Protection Agency (EPA) form the competent authority for the enforcement of COMAH [22]. In 2005, their COMAH regulations were updated to put added emphasis on the availability of information to the public [29]. For implementation of LUP, the HSE has published guidelines for acceptable risk levels, decision making procedures and its LUP decision matrix to achieve their roles of advising local planning agencies (LPA) and offering advice on proposed new developments [30].

The LUP process is initiated by the proposal for a new facility, modification of an existing facility or establishment within the separation distance of an existing facility. LPA receive the information for a proposal and pass it along to the HSE for consultation. The HSE evaluates the risk assessment and utilizes its Planning Advice for Developments near Hazardous Instillations (PADHI) system to set a consultation distance around the hazardous facility [22]. The area surrounding the facility, within the consultation distance, is broken down into three zones based on established risk criteria as the first part of the decision matrix. The second part of the decision matrix is the sensitivity of the proposed development. The HSE has distinguished four levels of sensitivity to consider in the decision making process. Level 4 is for the most sensitive populations such as large schools or hospitals while level 1 is for the general working population. Depending on the sensitivity of the proposed development within the particular zone, the HSE will either advise against or does not advise against based on their matrix in Table 11. The LUP process is displayed in Figure 4 below.

Table 11 - HSE's LUP Decision Matrix [19]

Level of Sensitivity	**Development in Inner Zone**	**Development in Middle Zone**	**Development in Outer Zone**
1	DAA	DAA	DAA
2	AA	DAA	DAA
3	AA	AA	DAA
4	AA	AA	AA

DAA = **D**on't **A**dvise **A**gainst development

AA = **A**dvise **A**gainst development

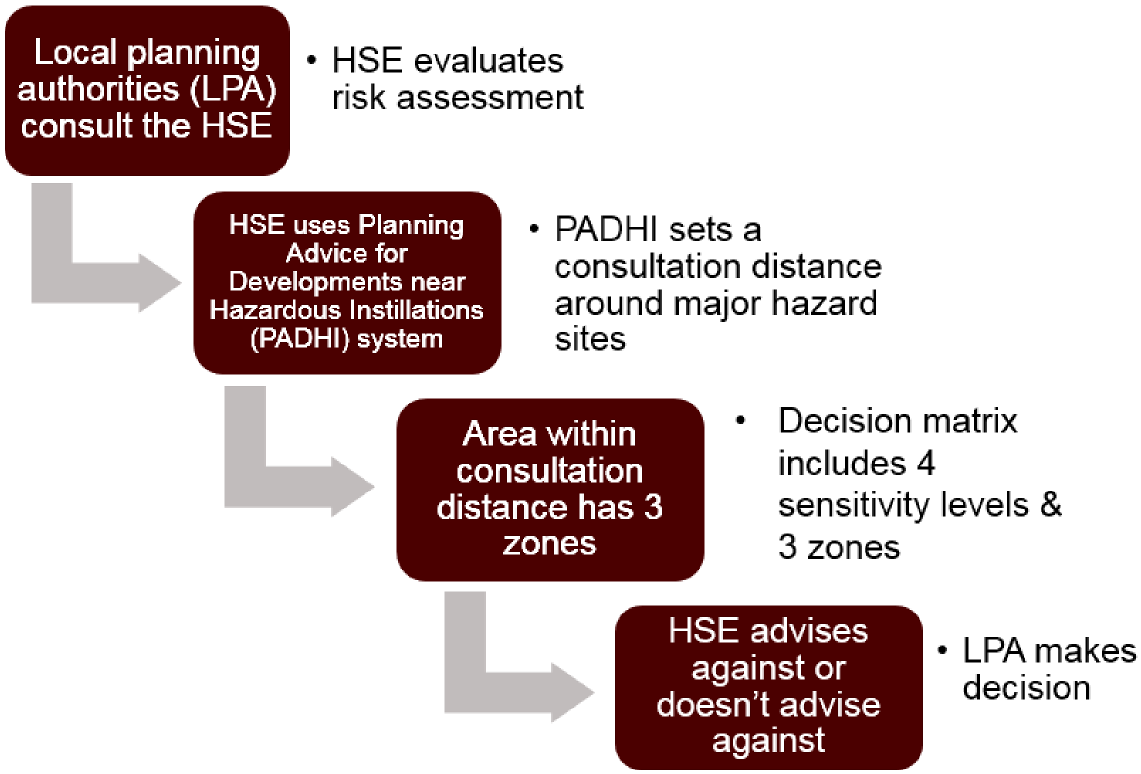

Figure 4 - UK LUP Process [19, 22]

The UK utilizes a combination of a CBA and RBA for the evaluation of major incident hazards. The HSE has employed different approaches depending on the substance and scenario in question. In cases of thermal radiation and explosions a CBA is used, while in the case of toxic releases a RBA is used [19, 30]. For both cases, the HSE has promulgated specific guidelines and tools to be used. Furthermore, the HSE provides guidelines for the adoption of as low as reasonably practicable (ALARP) principles to risk reduction measures.

Although the UK and the HSE are strongly centralized in respect to health, safety and the LUP process, the final decision for permitting new developments is up to the

LPA. In extreme cases, when the LPA does not follow the advice of the HSE, the HSE can apply to take over the decision-making responsibilities of the LPA. Another noteworthy aspect of LUP in the UK is the dual approach dependent upon the substance and scenario in question. This enables built in flexibility to evaluations used for LUP purposes.

11. NETHERLANDS

The substantial presence of oil and chemical industries in the relatively small country of the Netherlands led to the realization of the importance of LUP early on. Major implications of LUP in respect to hazardous facilities began because of public displeasure with industrial incidents occurring the 1960s. Public objection to industrial incidents led to the development of quantitative risk assessment (QRA) procedures. By the 1980s the Netherlands defined acceptable risk levels with the National Environmental Policy Plan [22]. The Spatial Planning Act and the Environmental Protection Act are the primary regulations regarding LUP in the country. They collectively address the process, procedures and the level of government that possess planning powers. In response to Seveso II Directive, the Dutch have implemented the Dutch Major Hazards Decree (BRZO) and the Dutch Public Safety Decree (BEVI) [30]. BEVI is pertinent to spatial decisions and planning for hazardous facilities and has increased the number of facilities that must perform QRAs.

The various acts relating to the protection of the environment has driven the Dutch government to construct a new piece of environmental regulation that combines existing acts. The new environmental code was published in 2016 and goes into effect in 2019 with the goal of increasing dialog between locals and government, simplifying the regulations into one for less clutter and standardizing the approach and decision making process [31].

Unlike the UK, the Netherlands has taken a more decentralized approach to their LUP policy. They have a multi-level system that includes the national, providential, and municipal levels. All three levels of government have separate planning powers depending on the facility in question. At the national level, the Housing, Spatial Planning and Environment Ministry (VROM) is the competent authority for the siting of facilities with a national interest, such as nuclear power plants. The providential level is the authority for facilities that fall under the top-tier Seveso classification, while the municipal level is in charge of lower-tier Seveso facilities. The competent governmental tier per facility is responsible for checking facility compliance with LUP and the validity of QRA analysis [30].

Similar to the rest of the EU, they have established tolerability criteria, guidelines and procedures to be followed at the national level. The Dutch are noted for their distinction between individual (10^{-6} per year for new facilities and 10^{-5} per year for existing facilities) and societal risk criteria ($10^{-3}/N^2$ for new and existing). Risk of 10^{-5} per year is tolerable for existing situations, but the goal is always 10^{-6} per year, adding flexibility to the planning process for existing LUP situations. Additionally, it allows the planning authority to take into account emergency notification and response when making decisions. Another distinct element of Dutch LUP is their use of risk maps. These are constructed using a national database as the source of information regarding probabilities and risk levels to facilities, and are used to inform the decision making process as well as the public.

The Netherlands is notable for its early and consistent implementation of a RBA to LUP. They require QRA with determination of end-points to create two LUP zones around hazardous facilities. In the area between the two separation distances, less sensitive establishments such as industrial complexes and recreational facilities are allowed. Within the outer zone, sensitive populations such as hospitals, schools and residential areas are prohibited. In the case of existing LUP situations, Dutch municipalities have the powers to expropriate. Although considered a last resort, the powers to expropriate in the Netherlands are relatively large compared to other countries for LUP purposes [32].

12. CURRENT STATUS OF THE UNITED STATES

The U.S. has been one of the leaders of industrial safety since the 1984 incident in Bhopal. There have been several laws and regulations passed with the unified goal of protecting employees and civilians against the hazards and risks created by hazardous chemical operations and facilities. However, developments have been slow and often implemented in response to major incidents. Many of the laws and regulations passed have touched on the subject, but none have directly addressed LUP as shown in Table 12. The Pipeline and Hazardous Materials Safety Administration (PHMSA) has published recommendations concerning siting requirements for liquefied natural gas (LNG) facilities, and the EPA has regulations concerning off-site consequences and calculation of separation distances. However, there is a lack of guidance for risk assessments and addressing conflicts between land uses in laws in the U.S. There are still many unanswered questions and issues to address in order for the U.S. to be able to implement a definitive LUP policy.

Table 12 - Relevant U.S. LUP Regulations

Agency	LUP Relation	CFR
OSHA	On-Site Siting	29 CFR Part 1910
ATF	Explosive materials	27 CFR Part 555
DOT	LNG Pipeline Facility Siting	49 CFR Part 193
HUD	Noise & Pollution Siting Requirements	24 CFR Part 51
EPA	RMP	40 CFR Part 68
	Standards for Owners	40 CFR Part 264
President Obama	Executive Order 13650	
California	Planning & Zoning law (2011)	
U.S. Constitution	Fifth Amendment	

12.1 EMERGENCY PLANNING AND COMMUNITY RIGHT TO KNOW ACT OF 1986 (EPCRA)

The tragedy at Bhopal was the first landmark incident that had a profound impact on industrial safety throughout the world. It highlighted the lack of regulations worldwide that required hazardous facilities to communicate with local communities concerning the hazards, risks and emergency planning preparation in case of an emergency. Several countries responded with regulations emphasizing these holes, including one in the U.S. known as the Emergency Planning and Community Right to Know Act of 1986 (EPCRA). Bhopal was the driving force Congress needed to address the clear lack of information on chemical hazards conveyed to the public. EPCRA has two main functions: (1) emergency notification and planning and (2) informing the public. The emergency planning portion of the act administers a framework to facilitate the dialog between hazardous facilities and local communities to set up emergency planning procedures. It also set up requirements for emergency notifications when an incident ensues. The community right-to-know portion of the act gave everyday citizens the rights to imperative information on the hazards and toxic chemicals present at industrial locations within their communities without requiring governmental mediation [33]. This act has been instrumental in providing the avenues for informing the public of hazardous chemicals within local communities; nonetheless, it is only the first step in protecting them.

12.2 CLEAN AIR ACT AMENDMENTS OF 1990 (CAAA)

The next major advancement in U.S. safety regulations was the Clean Air Act Amendments of 1990 (CAAA). A critical part of its amendments were the requirements for Occupational Safety and Health Administration (OSHA) and for the EPA to enact a chemical process safety standard to prevent accidental releases of hazardous chemicals. Section 304 of the CAAA calls for the Secretary of Labor, pursuant to the Occupational Safety and Health Act of 1970, to promulgate a chemical process safety standard [34]. In response, the Process Safety Management (PSM) rule was enacted in a fourteen-part OSHA standard that requires employers to perform a workplace hazard assessment, develop and maintain written safety information, train and educate employees, etc. The standard has been prominent in advancing employee safety for highly hazardous chemical facilities. PSM even goes as far as addressing facility-siting issues for facilities handling highly hazardous chemicals; however, this requirement only applies to onsite consequences. OSHA and PSM have been irreplaceable in developing regulations and enforcement for the protection of employee safety. Yet, their contribution to LUP and consequences "outside the fence" are minimal.

The more pertinent part of the CAAA to LUP noted in section 112(r) requires the EPA to establish guidelines for chemical accident prevention at facilities that use particular hazardous chemicals. This led directly to the enactment of 40 CFR Part 68, referred to as the Risk Management Plan rule. Part 68 is composed of the chemical accident prevention provisions and places the key requirements on employers to perform a hazard assessment, which includes an off-site consequence analysis (OCA), submission of a risk management plan and list of regulated substances and quantities [22]. OCA parameters such as endpoint determination and worst-case release analysis parameters are promulgated in 40 CFR Part 68.22 (a-g) and displayed in Table 13. Owners and operators of hazardous chemical facilities must use this data outline in Part 68.22 to determine distances to endpoints.

Table 13 - Endpoints & Parameters for Worst-case Scenario Analysis [35]

Endpoints	Toxics	Provided in appendix A of Part 68
	Explosion	Overpressure of 1 psi
	Radiant heat/exposure time	Radiant heat of 5 kw/m^2 for 40 seconds
	Lower flammability limit (LFL)	As provided by NFPA
Parameters	Wind speed/atmospheric stability class	Wind speed = 1.5m/sec F atmospheric stability class
	Ambient temperature/humidity	Highest temperature in last 3 years & average humidity[1,2]
	Height of release	Assuming ground level (0 feet)[1]
	Surface roughness	Rural or urban, as appropriate
	Dense or neutrally buoyant gases	Dispersion models shall appropriately account for gas density
	Temperature of released substance	Process temperature or highest daily maximum temperature based on last 3 years, whichever is higher[1]
[1] Alternative scenario analysis has different criteria [2] Data must be gathered at the stationary source or at a local meteorological station		

The regulations also call for the owner or operator to identify and analyze alternative release scenarios for each regulated toxic substance held in a process and at least one alternative release scenario to represent all flammable substances held in covered processes. Unlike the worst-case scenario analysis, the alternative scenario analysis is more likely to occur, therefore enhancing the ability to assign a more appropriate release height, temperate of released substance, and ambient temperature/humidity parameters. Enforcing the analysis of alternative scenarios is best for the owner, operator, and the local community. It provides more information regarding potential incident scenarios to the community and first responders while also covering more bases for the facility. 40 CFR Part 68.30 defines the criteria that the owner or operator shall use to define the offsite impacts in the RMP. The regulations call for an estimate of the population within the radius of the endpoint and examination of the presence of schools, hospitals, parks, major commercial areas, etc. This determination of impact to the surrounding population is essentially the second step in LUP, determining the consequences to the surrounding population. It also requires the owner or operator to review and update the OCA at least once every five years or if changes occur in the process, quantities stored or handled, or any other aspect that may change the calculated endpoint by a factor of 2.

The EPA in respect to OSHA is much more pertinent concerning LUP. OSHA is mandated with employee safety, dealing with onsite hazards and risk, but the EPA works with affairs off-site. RMP is the closest piece of regulation that the U.S. has to mitigate the impacts of LUP. It provides a good basis and starting point for the future implementation of LUP in the U.S. The EPA's RMP, which includes OCA, is only a part of a possible future LUP policy that sets about the requirements for facilities to submit risk management plans and the methodology, parameters and approach to be used to calculate safety distances. Still missing is guidance or regulation on how to use separation distances with LUP, how to handle future growth, how to handle existing facilities with LUP issues and how to enforce LUP. RMP addresses the need to determine separation distances but provides no requirements for them. A facility may determine that a school, hospital or highly populated residential area is within the radius of their calculated separation distances, but has no requirement or guidance on a plan of action to mitigate that risk. RMP and EPCRA are valuable pieces of regulation that help to inform the public and community of the hazards and potential consequences, yet the heart of a LUP policy is still missing in the U.S. and is one that shall be solved.

12.3 BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES (ATF)

The ATF has been given the authority to require separation distances for the storage of explosive materials to inhabited buildings, highways and railways [36]. In the CFR, the ATF has established three classes (high explosives, low explosives, or blasting agents) of explosive materials, and any material falling under the list of materials for either class shall be stored in compliance with the regulation. Separation distances are set based upon the class of the explosive material and the quantity of it stored. Section 555.201 of the CFR requires any person storing explosive materials to notify the official in charge of fire safety for the locality in which the explosive materials are stored of the type and location.

Much like the EPA's RMP, the ATF fails to provide guidance on LUP or actions to take in the event of a land use conflict. Although the ATF does a great job of defining separation distances for the storage of explosive materials, it is lacking regulations for governmental oversight, enforcement, and direction to counter LUP issues.

12.4 PRESIDENTIAL EXECUTIVE ORDER (EO) 13650

President Obama issued Executive Order (EO) 13650 "Improving Chemical Facility Safety and Security" on August 1, 2013 in response to tragic chemical facility incidents. The purpose of the EO was to enhance the safety and security of chemical facilities in an effort to minimize the risks present to communities, employees, operators and owners [37]. It set up a Federal working group of representatives from multiple agencies such as the EPA, DOT, OSHA and the DHS; pulling together subject matter experts in three areas relevant to LUP; modernizing policies and regulations, incorporating stakeholder feedback, developing best practices, and strengthening community planning and preparedness. These three components of the EO are, in many ways, the same aspects that are required for an effective LUP policy. Incorporating stakeholder feedback and developing best practices resembles the underlying goal of a LUP policy. Local communities are the driving force behind LUP, and the local stakeholders' feedback is a crucial part of its success. Improving State and Local Emergency Response Commissions and expanding the tools that assist them in the decision-making process for chemical facilities can be highly beneficial to the effectiveness and ability of local communities to make informed decisions regarding LUP.

One of the future actions of the working group, in respect to modernizing policies and regulations, is modernizing EPA's RMP regulation [38]. One way the EO hopes to achieve its goal of preventing chemical incidents is by updating RMP. This priority has led to proposed revisions to the accident prevention program requirements. The program requirements do not directly address LUP, but they could be forthcoming. The foundations of calculating separation distances and conducting an off-site consequence analysis are already promulgated in RMP. RMP is the closet regulation the U.S. has to a LUP policy, and building upon it to incorporate LUP is not out of the question. Perchance, modernization of the EPA's RMP could result in an amendment addressing existing facilities within communities, the future growth around a facility, new proposals for chemical facilities and authorization of a level of government to oversee LUP.

12.5 CALIFORNIA LUP

California's land use and planning law is a perfect example of the decentralized approach the U.S. has taken concerning LUP. The power to regulate private land use has been passed down from the federal government to the states, and, in turn, the states have passed it down to local communities. The California Constitution sets the premises that a county or city may set and enforce ordinances to protect the public health, safety and welfare of its residents [39]. The broad power to enact such ordinances allows the distinct legislative bodies across the state to implement a policy that fits their needs, yet the dynamic and complex nature of LUP provides a challenge. Therefore, the burden of creating, implementing, and enforcing a LUP policy lies with the legislative bodies of the counties or cities, with minimal state or federal oversight.

California Governmental Code Section 65100-65107 creates a local planning agency in each city and county with the powers necessary to carry out the purposes of LUP. The local planning agency is to be constructed of at least 5 members who all shall act in the public interest and report to the legislative body of each city or county [40]. Related to LUP, Article 2. Adoption of Regulations 65850 states the legislative body of any county or city may adopt ordinances that regulate the intensity of land use and the location, height, bulk, and size of buildings and structures. Essentially, it is granting local legislative bodies the power to set and enforce LUP policy as long as it complies with state and federal laws. Still, any type of guidance on how to achieve LUP goals is nonexistent. It is similar to EPA's RMP in the way that owners or operators must perform hazardous material risk assessment and certify whether or not a proposed project will have more than a threshold quantity of a regulated substance in a process. How to use that information for LUP purposes is still missing in regulations [41].

Setting up local planning agencies is a step forward for the U.S.'s ability to effectively implement a LUP policy. The heart of LUP lies within local communities, so the creation of local planning agencies is forward progress in getting the right people involved in the decision making process. Establishing a specific agency to handle such issues would be promising for LUP and the creation of a comprehensive LUP policy. Unfortunately, these are still far off from being met.

12.6 PIPELINE AND HAZARDOUS MATERIALS SAFETY ADMINISTRATION (PHMSA)

PHMSA is an agency within the U.S. Department of Transportation (DOT) that aims to protect people and the environment by enforcing standards, educating, and conducting research to prevent incidents in the transportation of energy. PHMSA is in charge of setting minimum safety standards for the siting of new LNG facilities, which the DOT received Congressional authorization for [10]. PHMSA addresses the siting requirements in respect to thermal radiation protection, flammable vapor-gas dispersion protection and wind forces. The CFR addresses these three factors, provides exceptions and details the modeling parameters that shall be used. NFPA (National Fire Protection Association) 59A-2001 is incorporated by reference in the CFR and contains the actual regulations concerning LUP in relation to new LNG facilities. The NFPA calls for provisions to be made to minimize the possibility of offsite consequences and defines procedures for calculating the possible effects of LNG facilities. The regulations apply to proposals for significant modification of existing facilities and to new LNG facilities after March 31, 2000, grandfathering LNG facilities constructed prior.

It addresses the key components of establishing acceptable criteria, defining procedures for assessment methods, preventing future developments and appointing competent governmental oversight but fails to address existing situations. It is only specific to only LNG facilities, as well. Nevertheless, 49 CFR 193 is the closest piece of regulation that the U.S. has to a LUP policy.

12.7 FIFTH AMENDMENT

The Fifth Amendment may be one more hurdle for a LUP policy in the U.S. to have to clear. An all-inclusive LUP policy will provide guidelines for the phasing-out or expropriation of land as a means to mitigate risk. This could be in the form of phasing-out or expropriation of hazardous facilities or private property surrounding a facility. Either way, controversy is eminent.

Among other things, the Fifth Amendment of the U.S. Constitution provides protection to private property owners. It states that in order for the government to take private property it must be for public use and require just compensation. The definition of “public use” has historically been interpreted relatively strictly compared to what LUP would require. However, in *Kelo v. City of New London* (2005), the Supreme Court loosely interpreted the definition of “public use” in favor of the governmental taking private property [42]. Although states have passed laws limiting the interpretation of public use, this decision opens the door of possibility for the LUP phasing-out and expropriation.

13. COMPARISONS

Comparisons between the major components of LUP policies around the world are helpful in an attempt to identify a best practice. Doing so, helps summarize the differences and identify the changes some countries have made. It is critical to be aware of the advancements countries have made in response to lessons they have learned and to learn from them as well. It is worth noting the changes France made in response to the incident in Toulouse, Germany's progressions towards a CBA, and the Netherlands emphasis on phasing-out and expropriation. Therefore, there is no reason for the U.S. to implement a policy and have to go through the same growing pains as another country.

Table 14 - Criteria & Approach Comparison

	Germany [17]	France [9]	UK [19, 23]	Netherlands [22, 43]	US [35]
# of Zones	2 or 3 [23]	4	3	2	1
Criteria	Based upon substance & quantity	4 zones in risk matrix based on gravity & prob.	Inner > 10^{-5} Middle >10^{-6} Outer > $\frac{1}{3} * 10^{-6}$	10^{-5} 10^{-6}	EPA's RMP - Endpoints
Approach	Generic/Consq.	Consq./Risk	Consq./Risk	Risk	Consq.

Table 14 shows the main differences between some of the world's most notable LUP policies. Germany is prominent for its reluctance to incorporate QRA into the LUP process, thereby employing a combination of GSD and CBA. Consequently, Germany bases its zone criteria on the substances and their quantities. France is known for its changes to its LUP in 2003. Feeling their existing policy was inadequate, France implemented a more thorough approach that incorporated probability assessments. France also, increased the use of maps and zones to inform the decision-making process as was seen in Table 9, Table 10 and Figure 3. The UK is notable for its unique combination for CBA and RBA. Moreover, the Dutch are notorious for their early and sole implementation of QRA. It is worth noting the U.S. is the only country in Table 14 that has only one LUP zone. This is due to the U.S. currently lacking a LUP policy and thus does not have a need for more zones. The general requirements of the EPA RMP call for end-point determination but do not set zoning or LUP restrictions that require the use of more zones.

Table 15 - Risk Reduction Techniques & Zoning Comparisons

<table>
<tr><th></th><th>France</th><th>UK</th><th>Netherlands</th><th>US</th></tr>
<tr><td>Community Awareness/ Emergency Response</td><td colspan="3">Seveso I Directive (82/501/EEC), Seveso III Directive (2012/18/EU)</td><td>Emergency Planning & Community Right to Know Act of 1986, EO 13650</td></tr>
<tr><td>Inherently Safer Design</td><td colspan="3" rowspan="2">Seveso II Directive (96/82/EC), Amendment in 2003 (2003/105/EC), Seveso III Directive (2012/18/EU)</td><td>Clean Air Amendments Act of 1990, EO 13650</td></tr>
<tr><td>Zoning/ Permitting</td><td>PHMSA, ATF, California LUP</td></tr>
<tr><td>Expropriation/ phasing-out in use</td><td>Prime Minister has closed and reduced activities of plants [23, 43]</td><td>Grandfathered in prior to 1999</td><td>Relatively large power to expropriate and has been used before [43]</td><td>Extremely rare</td></tr>
</table>

Table 15 displays the progress of four of the mentioned countries in their efforts to mitigate the risk surrounding hazardous facilities. The extent of LUP increases as you progress down the rows in the table. Community awareness and emergency response was the first step that several countries addressed in response to the gas leak in Bhopal, India. However, that alone is not sufficient in protecting the safety of employees and local communities. The next step was emphasis on inherently safer design and the implementation of state of the art safety technology. Countries have addressed the significance of inherently safer design to different extents. At one end of the spectrum, implementation of state of the art technology, regardless of cost, is enforced, and at the other end, cost-benefit analyses are used to determine the desired extent of implementation. The bottom two rows of Table 15 are where the separation between U.S. LUP policies and many other countries is evident. All EU member states are required to implement and enforce regulations for the zoning of hazardous facilities. The U.S., however, only has a state plan in California, PHMSA regulating siting of LNG facilities and the ATF regulating safety distances for the storage of explosives. All other chemicals, substances, states, and facilities not covered by these three pieces of legislation. Furthermore, in the U.S. it is almost unheard of for local communities to come together to push for phasing-out or expropriation are utilization for purposes of LUP.

14. PROS AND CONS OF IMPLEMENTING LUP IN THE U.S.

The U.S. currently has a number of regulations concerning safety distances to particular substances and LUP, creating jurisdiction confusion and overlap. Implementing an all-inclusive LUP policy that specifically addresses the key components of LUP (established tolerability criteria, defined approach and methodology, appoints competent governmental oversight, and addresses new and existing facilities as well as future growth around a facility) would eliminate this confusion and complexity. Separation distances and LUP provisions specified by particular industries or agencies such as the ATF for explosives or PHMSA for LNG facilities could be incorporated by reference in the new LUP policy. This allows competent authorities to establish LUP or separation distances that are at least as effective as the general provisions while also maintaining the new LUP policy as the foundation of LUP in the U.S. so that owners/operators and local planning authorities would always have the LUP policy to begin with. The jurisdiction confusion and overlap would also be minimized by appointing governmental oversight for LUP. Most importantly though, the fundamental reason for implementing a LUP policy in the U.S. is the reduction of potential consequences/risk to local communities with hazardous facilities. Limitations on land-use, restrictions for future growth and prescribed safety distances are mitigating measures used by LUP to reduce risk.

However, implementing a LUP policy in the U.S. will have its critics and drawbacks. A perfect LUP policy does not exist and it has already been mentioned the near impossible nature of identifying a universal best practice. Some people may object a change in LUP in the U.S., whether it is because they disagree with the approach, the costs, time and resources associated with LUP or the implications LUP has on urban and industrial development. In order for LUP to become heavily used in the U.S. more money, time and resources are required for the evaluation and calculation of separation distances. Setting up a LUP working group for competent governmental oversight also raises the costs of doing business. The primary drawback and cost of LUP will be the implications to urban and industrial development. A major part of LUP is the restrictions that it places on land-uses. It could be from limitations on developments, phasing-out or expropriation of establishments, or future restrictions within separation distances. Embargoing buffer zones around hazardous facilities will come at the cost of land development. Land within separation distances will not provide its maximum potential economically. Whether it is the hazardous facilities or local communities, someone will have to pay for the land within separation distances. This can be especially difficult for small companies who do not have a lot of money.

15. CONCLUSIONS

Oil, gas and chemical industries are an essential part of the economy and are not disappearing any time soon. They have the potential to improve people's lives, wellbeing and health as long as the risks involving the storage, handling and processing of hazardous chemicals are taken into account [37]. One way to address and mitigate the risks with LUP is to create buffer zones or implement development restrictions in the areas surrounding hazardous facilities. Unfortunately, the implementation and enforcement of adequate LUP is currently a near impossible accomplishment. An all-inclusive best practice has yet to be identified and is not a reasonable expectation, primarily due to the dynamic nature of communities, the diverse set of factors that must be integrated into a policy and the diversity of countries around the world. However, there are specific characteristics of LUP that should be accounted for.

LUP can be simplified into the key components of establishing acceptability criteria, approach/methodology, competent governmental oversight, new and existing facilities, and future growth. The establishment of acceptable criteria is closely connected with the application of LUP, on one hand, there is the motive to provide maximum safety; and on the other is the yearning to maximize the economic benefit of the surrounding areas. This creates quite the conundrum in trying to establish appropriate separation distances and developmental restrictions that provide adequate safety to the surrounding population while not hampering the economics of the community or facility. Ideally, separation distances should be large enough to ensure the safety of the surrounding population. Countries have tinkered with the exact value, but, generally, a risk of less than 10^{-6} per year is the acceptable threshold. A more stringent risk value of 10^{-5} per year is often used for more sensitive populations such as hospitals, schools and densely populated areas. In some cases, flexibility is introduced into the acceptable risk criteria by the ability of decision makers, in the planning process, to consider community preparedness and emergency response when determining acceptable risk criteria on a case-by-case basis. It is worth remembering that risk reduction techniques such as increased public awareness, improved emergency planning and inherently safer design can be used to lower separation distances and risk levels in addition to proper LUP. Some may believe that improving emergency response alone are the answer. However, a study found that the costs of improved emergency response was greater than the loss in value of restricted land use [43]. Also worth consideration is the notion that communities who do not have the technical expertise or infrastructure to sufficiently respond to hazardous incidents should not be approved as locations for oil, gas and chemical industries [4].

Landowners, local residents, developers, city officials and other members of the public all are affected by LUP decisions. Future growth of the community could be hindered by embargoing land in buffer zones or developmental restrictions that could have provided favorable economics. Proposals for new hazardous facilities within existing communities provide employment opportunities for the local residents. Hazardous facilities, such as the West Fertilizer Company, benefit the community with their services. LUP decisions have the greatest effect on local communities and thus should be involved in LUP.

Defining the criteria for separation zones, number of zones to be used, particular developmental restrictions within each zone and, to an extent, even the methodology used to apply LUP are just formalities in the decision making process. The differences of these factors between countries are minute and hardly affect the outcome of LUP. This conclusion is supported by the findings that no significant difference was found in safety performance amongst EU member states [28]. Thus, the specific criteria and approach are not as important as applicability and extent of LUP. The critical components are the abilities to enforce LUP decisions and to minimize the potential consequences/risk to the community. Having competent authorities involved in the evaluation process and land-use decision-making process is important to the success of LUP. Thus, a national working group that serves as the competent governmental oversight and works on harmonizing the approach used for LUP should be set up.

France aimed to improve the efficiency of their LUP regulations in 2003 by increasing the limitations on future constructions surrounding hazardous facilities, incorporating risk analysis in the decision making process and addressing the vital issue of dealing with existing problematic situations surrounding hazardous facilities. They directly addressed some of the key components of LUP they believed were previously inadequate. It is important to note the French realized adjustments could be made in regulations regarding existing facilities and restrictions on future growth; that urban development should not take precedence over safety. They also aimed to standardize their risk analysis procedures, a key component of applying LUP. Basing separation distances on inaccurate assessments leads to inadequate separation distances or excess amounts of land embargoed. Accurate assessments used in the LUP process are the foundation of LUP. Value lies in the lessons that France has learned and the changes that they have made to their LUP policy.

16. RECOMMENDATIONS FOR U.S. LUP

Across the U.S., states and cities coexist with very different economic landscapes. The application of LUP and what is best practice for LUP in Alaska will be very different from a more industrial state such as Illinois or Texas. Thus, flexibility should be incorporated into the approach and methodology used for LUP in the U.S. At the national level, the EPA promulgates a LUP policy that specifies minimum safe operation distances to sensitive population areas, acceptable criteria and defines the approach. The EPAs RMP has already established end-point criteria for the evaluation of hazardous facilities using a consequence-based approach. Keeping this approach, the EPA promulgates a LUP policy that requires mitigation of consequences in the event of establishments within two defined safe operation distances. For example, in the event of thermal radiation, separation distances could be defined as 5 kW/m^2 (inner zone) and 3 kW/m^2 (outer zone). Guidelines are required at the national level to address existing facilities, future growth and developmental restrictions. If hazardous facilities cannot utilize safety precautions and inherently safer design to minimize safe operation distances within acceptable levels then phasing-out or expropriation is desired. However, grandfathering existing facilities may be the only solution because phasing-out and expropriation in the U.S. is complicated by the Fifth Amendment and capitalism. Nevertheless, local communicates with existing hazardous facilities creating LUP issues should seek agreements with local residents and the hazardous facilities for reducing the potential effects of an incident. Guidelines promulgating developmental restrictions for land within each separation zone are also required. Within the inner zone, (smaller separation distance) future growth and new establishments are prohibited. For the land between the two separation distances, schools, hospitals and densely populated establishments shall be prohibited. Proposals for the modification or expansion of existing facilities shall be prohibited if additional establishments are included within separation distances or the consequences are increased. Establishing a competent national working group whose goal is to harmonize the approach, provide consistency to LUP enforcement, and verify LUP calculations, is also necessary. Competent governmental oversight provided by a national working group within the EPA would also provide assistance to local or state planning authorities who make the LUP decisions.

Flexibility is important to the ability to apply LUP to all 50 states with their various political, economic, urban and technological environments. Thus, states shall be allowed the option to implement state LUP policies that are at least as effective as the national regulations. This permits states the ability to implement or incorporate a risk-based approach. The criteria for the two risk-based separation zones would be established by the national working group (10^{-6} for outer zone of new facilities, 10^{-5} for inner zone of new facilities). A risk-based approach may be preferable to highly industrialized states that place a very high value on land uses within cities such as Houston. While, states such as Alaska, will likely not prefer the additional costs, time and resources that a risk-based approach requires. States, who implement a LUP plan, shall set up a state level planning authority to implement and enforce the policy. The national working group reserves the right to audit the state level LUP policy to ensure it is at least as effective, within compliance and being adequately enforced.

LUP in the U.S. is community driven, especially for existing situations, and thus, should been involved in the decision-making process. Calculations of separation distances should be checked by the state or national working group but locally discussed. Calculations should also be made available to the public and shall be discussed with local planning authorities who have a stake in the decisions. Local planning authorities should also consult the state or national working group when development proposals arise near calculated separation distances.

It would be a shame if it takes another incident like the one in West, Texas before the U.S. implements a LUP policy. The Congressional Research Service of the U.S. found thousands of facilities in all 50 states, which contain hazardous substances that present risk to Americans living nearby. Texas alone has over 1,400 facilities. They also found 89 facilities within the U.S. that put more than one million people at risk [44]. Incidents like Bhopal, AZF, West and Tianjin are waiting to happen all across the country. Effectively mitigating these risks using LUP in the U.S. by addressing the issue of hazardous facilities in close proximity to local communities will help preserve the country and prevent such disasters.

REFERENCES

1. Kletz, T., *Still Going Wrong!* 1st ed. Case Histories of Process Plant Disasters and How They Could Have Been Avoided. 2003, United States: Gulf Professional Publishing.

2. Porter, S. and J. Wettig, *Policy issues on the control of major accident hazards and the new Seveso II directive1*. Journal of Hazardous Materials, 1999. **65**(1–2): p. 1-14.

3. Sharma, D.C., *Bhopal: 20 years on.* The Lancet, 2005. **365**(9454): p. 111-112.

4. Broughton, E., *The Bhopal disaster and its aftermath: a review.* Environmental Health, 2005. **4**: p. 6-6.

5. Shrivastava, P., *Managing Industrial Crisis.* New Delhi, Vision Books, 196, 1987.

6. *Accident Summary, Union Carbide India Ltd., Bhopal, India: December 3, 1984*. 2004, Health and Safety Executive: Hazardous Installations Directorate.

7. Nicolas Dechy, T.B., Nadine Ayrault, Marie-Astrid Kordek, Jean-Christophe Le Coze, *First lessons of the Toulouse ammonium nitrate disaster, 21st September 2001, AZF plant, France.* Journal of Hazardous Materials, 2004. **111**(1–3): p. 131-138.

8. Dechy, N., S. Descourrières, and O. Salvi, *The 21st September 2001 disaster in Toulouse: an historical overview of the Land Use Planning*, in *Proceedings of the 28th ESReDA Seminar on the Geographical Component of Safety Management: Combining Risk, Planning and Stakeholder Perspectives*. 2005: Karlstad University, Sweden.

9. Taveau, J., *Risk assessment and land-use planning regulations in France following the AZF disaster.* Journal of Loss Prevention in the Process Industries, 2010. **23**(6): p. 813-823.

10. U.S. Chemical Safety and Hazard Investigation Board, *West Fertilizer Final Investigation Report*, in *West Fertilizer Company Fire and Explosion*, C.S. Board, Editor. 2016, Chemical Safety Board: U.S. Chemical Safety and Hazard Investigation Board.

11. McLennan County Apraisal District Map Search, *Property Search Results: Property ID 201357, Adair Grain, Inc.* 2013.

12. Veronica A Tinney, J.M.D., Lucy Sciallo-Tyler and Jerome A. Paulson, *School Siting Near Industrial Chemical Facilities: Findings from the U.S. Chemical Safety Board's Investigation of the West Fertilizer Explosion.* Environmental Health Perspectives, August 2, 2016: p. 4-8.

13. *ATF Announces $50,000 Reward in West, Texas Fatality Fire*, T. Bureau of Alcohol, Firearms and Explosives, Editor. 2016, Houston Field Division: Published Online.

14. Fu, G., J. Wang, and M. Yan, *Anatomy of Tianjin Port fire and explosion: Process and causes.* Process Safety Progress, 2016. **35**(3): p. 216-220.

15. Hernandez, J.C. *Tianjin Explosions Were Result of Mismanagement, China Finds*. The New York Times Online, 2016.

16. Huang, P. and J. Zhang, *Facts related to August 12, 2015 explosion accident in Tianjin, China.* Process Safety Progress, 2015. **34**(4): p. 313-314.

17. Christou, M.D. and M. Mattarelli, *Land-use planning in the vicinity of chemical sites: Risk-informed decision making at a local community level.* Journal of Hazardous Materials, 2000. **78**(1–3): p. 191-222.

18. Christou, M.D., A. Amendola, and M. Smeder, *The control of major accident hazards: The land-use planning issue.* Journal of Hazardous Materials, 1999. **65**(1–2): p. 151-178.

19. Savage, D. *HSE's Land Use Planning Methodology, Health and Safety Executive*. [cited 2016 March-April].

20. *Airport Watch Briefing - Third Party Risk around airports*, A.E. Federation, Editor. March 2009. p. 1.

21. Mishra Pradyumna, S.R., Pathak Neelam , Jain Subodh, Banerjee Smita, Maudar Kewal, *Bhopal Gas Tragedy: review of clinical and experimental findings after 25 years.* International Journal of Occupational Medicine and Environmental Health, 2009. **22**(3): p. 193-202.

22. Pasman, H.J., *Risk Analysis and Control for Industrial Processes - Gas, Oil and Chemicals: A System Perspective for Assessing and Avoiding Low-Probability, High-Consequence Events*. 2015, United States: Elsevier Science.

23. Claudia Basta, M.S.a.M.C., *Overview of Roadmaps For Land-Use Planning In Selected Member States*, in *Implementing Art. 12 of the Seveso II Directive*, E. Commission, Editor. 2008, Institute for the Protection and Security of the Citizen: JRC Scientific and Technical Reports. p. 53 - 77.

24. *SFK/TAA-GS-1k - Recommendations for separation distances between establishments under the Major Accidents Ordinance and Areas requiring protection within the framework of land-use planning - Implementation § 50 BImSchG SFK / TAA Working Group "Land-use planning"* German Hazardous Incidents Commission (SFK) and the German Technical Committee for Plant Safety (TAA), Editor. 2005, Federal Ministry for Enviornment, Natural Conservation and Reactor Safety.

25. *KAS-18. K - Recommendations for separation distances between establishments covered by the Major Accidents Ordinance (Störfall-Verordnung) and areas worthy of protection within the framework of land-use planning implementation of Article 50 of the Federal Immission Control Act (Bundes-Immissionsschutzgesetz, BImSchG (short version)*, Commission for Plant Safety (KAS), Editor. 2010: Federal Ministry for Enviornment, Natural Conservation and Reactor Safety.

26. *Technological risk prevention plan (PPRT)*, Ministry of Ecology and Sustainable Development, Editor. 2006.

27. Cozzani, V., et al., *Application of land-use planning criteria for the control of major accident hazards: A case-study*. Journal of Hazardous Materials, 2006. **136**(2): p. 170-180.

28. Pasman, H. and G. Reniers, *Past, present and future of Quantitative Risk Assessment (QRA) and the incentive it obtained from Land-Use Planning (LUP).* Journal of Loss Prevention in the Process Industries, 2014. **28**: p. 2-9.

29. *Be prepared - COMAH Regulations 2015*. Seveso III Directive 2014 [cited 2016 August 12].

30. Claudia Basta, J.M.M.N., Sisi Zlatanova and Ben Ale, *Risk-maps informing land-use planning processes: A survey on the Netherlands and the United Kingdom recent developments.* Journal of Hazardous Materials, 2007. **145**(1–2): p. 241-249.

31. *Environmental code: state of play and implementation*. Environmental Code - Introduction 2016 [cited 2016 September].

32. F.A.M. Hobma, P.J., *Planning and Property Rights*, in *Planning and Development Law in teh Netherlands An Introduction*, S.I.v. Bouwrecht, Editor. 2016, 's-Gravenhage. p. 24-26.

33. Ward, D.H., *Prospects for Safer Communitites: Emergency Response, Community Right to Know, and Prevention of Chemical Accidents.* Harvard Environmental Law Review, 1990. **14**(1): p. 135-188.

34. Alexis M. Herman, C.N.J., *Process Safety Management OSHA 3132*, O.S.A.H. Administration, Editor. 2000 (Reprinted).

35. Agency, U.E.P., *Title 40*, in *Part 68 Chemical Accident Prevention Provisions*. 1996: Code of Federal Regulations.

36. *Commerece in Explosives*, in *27*. Code of Federal Regulations Part 555.

37. *Executive Order 13650 Actions to Improve Chemical Facility Safety and Security*, The White House, Editor. 2013, Office of the Press Secretary.

38. *Actions to Improve Chemical Facility Safety and Security - A Shared Commitment*. 2014: US Environmental Protection Agency.

39. Christine Dietrick, J.A., *Land Use 101*, C.o.S.L. Obispo, Editor. 2013, League of California Cities. p. 1 - 2.

40. *Planning and Land Use*, in *Title 7. Chapter 3. Local Planning, Article 1. Local Planning [65100 - 65107]*, C.G. Code, Editor. 1984.

41. Cox, C., *Planning, Zoning, and Development Laws*, S.o.C. Governor's Office of Planning and Research, Editor. 2011. p. 40-48 , 103.

42. Stevens, J., *KELO et al. v. CITY OF NEW LONDON et al.* , S. Court, Editor. 2005.

43. *Risk-based Land Use Planning Guidelines*, Major Industrial Accidents Council of Canada, Editor. June, 1995. p. 14 - 31.

44. Solids, P.B. *What State Has the Most Hazardous Chemical Plants?* 2014 [cited 2016 June].