Discussion: Risk-Informed Land Use Planning

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Purpose

To meet the requirements of the Pipeline Safety Improvement Act (PSIA) of 2002, the U. S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA) contracted with the Transportation Research Board (TRB) to conduct a study of land use practices, zoning ordinances, and preservation of environmental resources with regard to transmission pipeline rights-of-way and their maintenance. In response to the recommendations of TRB Special Report (SR) 281, *Transmission Pipelines and Land Use: A Risk-Informed Approach*, PHMSA initiated and supports a collaborative effort by stakeholders, known as the Pipelines and Informed Planning Alliance (PIPA), to develop risk-informed land use planning guidance. This discussion summarizes the concepts of risk and risk management strategies, the risk characterization practices in the pipeline industry, the TRB recommendations for risk-informed land use guidance, and the role of risk in land use decision-making near transmission pipelines.

Concepts of Risk and Risk Management Strategies

What is risk?

Risk is a concept used to characterize the magnitude of negative consequences and the likelihood of the consequences occurring. The mathematical expression for risk is:

Risk = Likelihood x Consequence

As described in TRB SR 281, sound risk assessment practice attempts to answer the following questions:

- What can go wrong?
- How likely is it?
- What are the consequences?

Because of the complexity of precise calculation of risk, the results of the risk assessment process are often termed "risk insights," which are often used to inform decision making by operators and regulators.

Terms related to risk assessment that can lead to confusion include "hazard" and "threat". *Hazard* means a material or condition that could produce an adverse health or safety impact (e.g., natural gas in a pipeline under pressure). *Threat* means a physical process that could cause the hazard to produce such an effect (e.g., severe corrosion of the pipeline or careless excavation that could damage the pipeline).

What are the elements of risk management?

Risk management processes for transmission pipelines involve the following elements:

- *Identify* threats to the transmission pipeline system and pipeline locations where failure would have the greatest consequences.
- *Assess* and quantify risk.
    - Assemble data about the transmission pipeline system's susceptibility to the threats.
    - Integrate the data in a risk model.
- *Evaluate* the results to make and implement risk-informed decisions.
    - Rank pipeline segments by risk.
- *Mitigate risk* – identify, evaluate and implement additional prevention and mitigation measures to reduce risk.
- *Monitor* the effectiveness and modify the risk management process as needed.

There are many sources to learn more about risk management. One might begin by using an online *search engine, such as* www.google.com *to search on related terms.*

Why is risk a useful metric?

Transmission pipeline operators must comply with regulatory requirements developed to assure that their pipelines are constructed, maintained and operated safely. Over the last several decades, improvements have been made in pipe materials, fabrication and installation techniques, and post-installation operating and maintenance practices. Transmission pipeline systems have diverse operating and geographical characteristics which can result in varied susceptibility to threats to their integrity. Susceptibility to specific threats can, at times, lead operators to employ practices in excess of the regulations.

As a result of federal safety regulations regarding pipeline integrity management, transmission pipeline operators collect extensive data about the characteristics of the pipe, the environment near the pipeline, historical operating and maintenance practices, and the concentrations of people near the pipeline. Combining data and institutional knowledge, an operator can develop a clear understanding of its systems and can develop an objective method to determine how and where to focus resources and enhance operating and maintenance practices. Data evaluation can help the operator determine which practices are most effective. Risk is the best, perhaps only,

metric to enable an operator to consolidate information on the pipeline characteristics in support of decisions on allocating resources to address recognized, diverse safety issues on its systems.

Risk Characterization Practices in the Pipeline Industry

What do we know about the causes of transmission pipeline failure? What are the implications to land use near transmission pipelines?

Transmission pipeline incidents may be caused by a variety of threats. PHMSA develops and reports data on pipeline incidents and their causes on its Stakeholder Communications website. (Note that "incidents" is the term used in federal pipeline safety regulations to describe reportable events for gas transmission pipelines. "Accidents" is the term applied to reportable events for hazardous liquid pipelines. For this paper, "incidents" is used to refer to both.)

Threats to a transmission pipeline that are considered *beyond* the pipeline operator's control include third-party excavation damage and damage from natural forces (e.g., wind, rain, floods, lightening, and earth movement). Together these threats make up the largest category of causes of transmission pipeline incidents. Threats *within* the pipeline operator's control can also contribute significantly to the occurrence of incidents. These may include corrosion, operator error, and improper maintenance practices.

If only *serious* incidents (i.e., those resulting in a fatality or injury requiring in-patient hospitalization) are considered, over the period from 2003 to 2007 excavation damage was reported as the cause in 26.7% of hazardous liquid pipeline incidents and 30% of gas transmission pipeline incidents.

2003 – 2007 Approximate Percent of Serious Transmission Pipeline Incidents by Threat

Threat	Gas Transmission Pipelines	Hazardous Liquid Pipelines
Excavation Damage	30.0	26.7
Natural Force Damage	6.7	0.0
Corrosion	6.7	20.0
Human Error	20.0	13.3
Material Failure	10.0	6.7
All Other Causes	26.7	33.3

Source: PHMSA Significant Incident Files April 15, 2009

Land use planning near pipelines can influence the level of threat to the pipeline from third-party excavation damage. Increased excavation and development near a pipeline can threaten pipeline integrity and the safety of those that live and work nearby.

What decisions do existing integrity management regulations require operators to make using a characterization of pipeline risk?

Federal pipeline safety integrity management regulations require pipeline operators to develop and maintain programs to assess pipeline risk and use risk information as part of their efforts to ensure pipeline integrity and to protect high-consequence areas (HCAs) adjacent to pipelines. Provisions of these integrity management rules include:
Establishing risk-based schedules to conduct integrity assessments on highest risk pipeline segments first.
Evaluating risks to identify the intervals for periodic integrity assessment of individual pipeline segments (with maximum intervals prescribed in the regulations).
Integrating information that can impact the risks to pipeline integrity and the consequences of pipeline failure.
Performing risk analyses of pipeline segments to evaluate the need for additional preventive and mitigative actions to protect HCAs. The analysis of the effectiveness of the additional actions requires assessment of the magnitude and nature of risks along different pipeline segments and the effect of the actions on risk.
Evaluating the need (in hazardous liquid systems) for emergency flow restriction devices and enhanced leak detection systems.

The concept of "class locations" is one example of how population densities and surrounding land uses are incorporated in pipeline safety regulations. Pipeline locations are classified in 49 CFR 192.5 on the basis of population density in the vicinity of natural gas pipelines. More conservative operating constraints are specified as human population density increases. Each class location has requirements on the depth of cover of the pipe and the maximum stress level to which the pipeline is allowed to operate.

In practice, operators periodically survey their pipelines to identify areas where new development has occurred and determine whether the development has produced a required change in the class location. Where a change in class location has occurred, the operator must either lower the system operating pressure to meet the required stress level or replace the pipe with stronger pipe.

What approaches do operators use in characterizing transmission pipeline risk?

Transmission pipeline operators currently employ four basic types of risk analysis models in order to evaluate and rank pipeline segments.

All models require the collection of location-specific pipe characteristic data related to the threats. This typically includes the pipeline design, operation, and maintenance variables that are thought to affect the likelihood of failure. Data is also collected about variables that reflect conditions surrounding the pipeline (e.g., population density and sensitive environmental resources) that relate to the potential consequences of failure of a segment.

In quantitative models, algorithms using this data are used to estimate risk. Other models are qualitative and use company expert opinion. Models may incorporate both quantitative and qualitative elements.

Most risk models provide relative measurements of risk (how the risks of different segments compare) rather than specific quantitative measures. They are used to determine which

transmission pipeline segments pose the highest risk. The numerical representation of risk from a relative-risk model at one company does not correspond to the same degree of risk at another company. A relative-risk model does not estimate actual risk, such as the annual risk of death to an individual residing near the pipeline.

Index Models

Index models are quantitative tools and provide operator-specific, relative risk ranking. They are the most frequently used risk models.

Operator-specific numerical scores are assigned to the model variables based on the known pipeline characteristic data. These numerical scores are then combined according to a subjective assessment of their importance, using weighting factors, and an index or score is calculated. The scores characterizing the relative likelihood of a failure are combined with those relating to consequences to arrive at a score representing the relative risk by each transmission pipeline section.

Risk Estimation Models

Risk estimation models are quantitative methods that use the characteristics of sections of the pipeline and the surrounding area to derive an estimate of the actual risk for each pipe segment. In risk estimation models, the likelihood is estimated as the expected probability of failure along the segment over a year's time. Consequences are estimated in categories such as economic loss, fatalities, and/or residual spill volume after clean-up (as an indicator of long term environmental damage). Risks associated with each threat for a section are calculated as the product of the likelihood of a failure and the expected consequences from that failure. The total risk for each section is estimated as the sum of risks from individual threats over all threats and subsections. The model output is an actual measure of risk.

Scenario-Based Approaches

Scenario models are qualitative and use an inductive approach to develop incident sequences (or scenarios). A particular occurrence or initiating event that has the potential to result in a transmission pipeline leak or failure is assumed, and possible scenarios that could evolve are then developed. Scenario approaches allow the time-sequencing of events and incident progression following a pipeline failure to be clearly described; index models do not.

In a scenario-based approach probabilities are qualitatively estimated for the initiating event and each of the successive events in the scenario, to derive likelihood estimates for the scenario. Consequences are qualitatively estimated to reflect the conditions resulting from the sequence of events in the scenario. The numbers of scenarios that are produced depend on the level of detail employed in the model.

Scenario-based approaches employ the same type of data as index and risk estimation models but the data are typically used in conjunction with a group evaluation process, rather than a model algorithm. The result is a relative risk ranking of pipeline segments.

Subject Matter Expert Approaches

Similar to scenario-based approaches, subject matter expert (SME) approaches utilize a panel of senior-level personnel having in-depth knowledge of the transmission pipeline system to identify various threats to pipeline integrity and the associated consequences in HCAs from pipeline operations. The SME process may also be used to provide inputs to one of the other types of risk assessments.

For the SME approach to be effective, the "expert individuals" must represent the major areas of transmission pipeline activities such as operations, engineering, cathodic protection, and assessment/testing. To be effective, this method requires that data related to pipeline integrity and the potential consequences of failure be readily available to support characterization of the identified threats and consequences. A process to rank the threats according to the collective judgment of the panel is followed and a basis for the judgment is documented. The result is a relative risk ranking of transmission pipeline segments.

What do operators know about the range of impact (consequences) of potential ruptures in their pipelines?

In the case of hazardous liquid pipelines, federal pipeline safety regulations require operators to identify the pipe segments that "can affect" pre-established HCAs. These pre-established areas include populated areas, areas unusually sensitive to environmental damage and commercially navigable waterways. In most cases, the operator has performed "can affect" analyses that take into account, at a minimum, a spectrum of leak sizes, the operator's leak detection capability and ability to mitigate the effects of spills, considering the terrain between the pipeline and the HCA.

In the case of gas transmission pipelines, pipeline operators are required by the integrity management regulation to evaluate their entire pipeline systems to determine which segments, if they were to rupture, would impact areas having prescribed population characteristics. The extent of impact of a gas transmission pipeline rupture is described by an equation that determines the "potential impact circle" (PIR). While a circle is used to estimate the range of impact of a pipeline rupture, the actual observed burn area is typically elliptical, and the application of the circle in identifying HCAs is defined to address this difference.

The integrity management regulations require that changes in land use trigger a reevaluation of potential HCA's. This ensures that pipelines near new high consequence locations are incorporated into an operator's integrity management program.

How does a gas pipeline fail and what is the potential impact?

The impact of a natural gas transmission pipeline failure is influenced by the length, depth and type of defect and whether the pipeline fails by puncture or rupture. It is dependent on the pipe diameter, wall thickness, material properties and operating pressure. At failure, the soil surrounding the pipeline at the rupture site will be forcefully expelled, leaving a crater. A mushroom shaped cap is formed by the cloud of escaping gas, which increases in height above the release point and is fed by the gas jet and entrained air from the plume which follows. In addition to entrained air, the release can also result in entrainment of ejected soil into the cap and plume. Eventually the cap will disperse and a plume will remain.

Ignition can occur at any time during the release. If ignition occurs immediately after rupture, a fireball will result. The fireball typically lasts for up to thirty seconds and then the gas burns as a large flame. There will not be a fireball if the release does not ignite shortly after rupture. Depending on the failure mode, the gas can be released with a wide range of different speeds and directions.

The levels of thermal radiation vary with time after rupture and with distance from the release point. People can become casualties as a result of receiving large doses of thermal radiation, and buildings can be ignited by thermal radiation directly from the fire or from secondary fires (e.g. from burning vegetation). A number of different criteria can be used for predicting casualties which should also take into account the distance from the pipeline and the availability of shelter.

The calculated consequence distances (potential impact circle) represent the distance beyond which people would be expected to escape to safety and the distance up to which houses would be predicted to catch fire. These calculations take account of the time-dependent nature of the event, and the variations due to the effects of parameters that cannot be known in advance of the event, such as the prevailing weather conditions or the crater source conditions. The results can range from a few meters for vertical puncture releases to distances up to several hundred meters for rupture releases, depending on the initial pipeline operating pressure that is assumed.

How does a hazardous liquid pipeline fail and what is the potential impact?

The consequences of a hazardous liquid pipeline failure depend on the product being transported, the manner in which the pipe fails, the operating pressure, and the geographical location of the failure. The major hazards associated with hazardous liquid products transported by pipeline are flammability and toxicity. Unlike natural gas, hazardous liquids spilled from a pipeline accident can flow away from the rupture site and generally don't dissipate into the air. This can result in environmental degradation and can threaten drinking water supplies.

Just as with natural gas, petroleum liquid products are flammable and can result in fire or explosions under certain conditions. In the case of liquid releases, the area impacted from a fire or explosion can be some distance away from the pipeline release, to where liquid flowed and pooled before igniting. Other hazardous liquid pipelines transport chemicals such as ammonia, which are toxic above certain airborne concentrations.

Both of these types of hazards, fire/explosion and toxicity, can affect the safety of personnel and the public in the vicinity of the structural failure and along the flow path of the released liquid. A flammable vapor cloud can form after a hazardous liquid pipeline or tank fracture and, if an ignition source is present, the cloud can detonate or explode. In the case of a crude oil or gasoline pipeline failure, a toxic cloud may also develop due to the presence of hydrogen sulfide (H_2S). Even in low concentrations, inhalation of H_2S may cause physical impairment or death.

What strategies can be used to reduce risk for existing pipelines?

Federal pipeline safety regulations, which are often closely related to various national consensus standards, require transmission pipeline operators to carry out preventive and mitigative activities to address threats to pipeline integrity, which experience has shown to be important. As described above, the recent integrity management regulations require operators to rigorously assess the physical condition of pipe segments with the potential to impact high consequence areas, and to remediate defects identified during these assessments. Stakeholders can also take steps to reduce risks associated with transmission pipelines by understanding the risks related to the pipelines and what they can do to reduce the threats to the pipelines through risk-informed land use planning.

TRB Recommendations for Risk-Informed Land Use Planning Guidance

The recommendation to PHMSA in TRB Special Report 281 is that risk-informed guidance should address:

1. Land use policies affecting the siting, width, and other characteristics of new transmission pipeline corridors;
2. The range of appropriate land uses, structures, and human activities compatible with transmission pipeline rights-of-way;
3. Setbacks and other measures that could be adopted to protect structures that are built and maintained near transmission pipelines; and
4. Model local zoning ordinances, subdivision regulations, and planning policies and model state legislation that could be adopted for land uses near transmission pipelines.

Such a risk-informed guidance system should include three interrelated components:

1. A decision framework informed by risk analysis;
2. Guidelines based on the analysis; and
3. Alternative actions that could be taken on the basis of the guidelines.

The process for developing risk-informed land use guidance should:

1. Involve the collaboration of a full range of public and private stakeholders (e.g., industry and Federal, state, and local governments);
2. Be conducted by persons with expertise in risk analysis, risk communication, land use management, and development regulation;
3. Be transparent, independent, and peer reviewed at appropriate points along the way; and
4. Incorporate learning and feedback to refine the guidance over time.

What does TRB SR 281 say about the important components in risk-informed land use decisions?

A systems approach to risk management that uses quantifiable mitigation measures (such as setbacks, warning signs, and alarm and evacuation procedures) and prevention measures (such as design, inspection, and maintenance of pipelines) would likely improve transmission pipeline safety across the nation. The TRB report suggests that the methodology should involve the following principal components:

1. *A high-quality, national level risk assessment* that acknowledges various classes of pipelines, their risk profiles and the variety of conditions that exist in the field;
2. *Simple and easy-to-use decision-guiding tools* with regard to risk levels associated with various extents of setbacks, rights-of-way, and procedures involved in maintenance, inspections, and mitigation in emergencies;
3. A *management plan for implementation* that renders help to local communities according to need and incorporates feedback from use of the approach in the field;
4. A *management plan for long-term communication* of risk and input from all stakeholders, especially transmission pipeline operators, local officials, and the public; and
5. A *management plan for integrating* all the preceding components and refining them on a continuing basis using actual experience.

Overview of the Role of Risk in Land Use Planning - Risk-Informed Decision Making and Communication

How has risk-informed land use planning near transmission pipelines evolved and what is the current state?

Land use planning near transmission pipelines is a subset of land use planning near hazardous facilities, which has its roots in the Seveso Directive in 1982. The best-known consequence of the Seveso disaster was a European Community (EC) regulatory framework for ensuring the safety of hazardous installations. Prior to the Seveso Directive there was no requirement for public information about major industrial hazards and appropriate safety measures in the event of an accident. The Seveso Directive was the first time that the principle of "need to know" was enshrined in EC legislation. It expanded the scope of public information and public participation in decision-making. Other results of the Seveso Directive were planning for off-site emergencies and multiple aspects of industrial safety. It also equalized the burden of regulation on industry across the EC.

In 1999, the Seveso II Directive introduced new requirements relating to safety management systems, emergency planning, land-use planning and the reinforcement of inspections. It was aimed at prevention of major-accident hazards involving dangerous substances and at limiting their consequences if they occurred. The document, Guidance on Land Use Planning, was released but is not legislation. The Directive excluded but required further investigation of the transport of dangerous substances by pipelines.

Canada followed the EC's path. In the late 1980's, increasing pressure from citizens' action groups and a growing body of regulatory legislation encouraged Canadian industry to adopt a proactive approach to disaster planning. In 1991, the Major Industrial Accidents Council of Canada released a national standard on emergency planning for Canadian industry, followed by a standard for land use planning in 1995. In 2004 the Canadian Standards Association issued CSA Plus 663: Land Use Planning for Pipelines: A guideline for local authorities, developers, and pipeline operators. (Link to the Canadian Energy Pipeline Association (CEPA) publications website, which includes a link to access the CSA Plus 663 document.)

Highly-structured quantitative risk characterization is mandated as part of land use near hazardous facility decisions in the UK, Canada, European Union, Australia and New Zealand. Risk-informed land use planning guidance specific to pipelines exists in the UK, Canada, Israel, Netherlands and the European Union. However, virtually no similar national approaches exist in the U.S. Land use planning in the U.S. is usually performed at the local community level, and planners generally do not require risk-based or risk-informed evaluations. They typically do not have experience evaluating risks associated with siting new developments near existing hazards. The California Department of Education is one example of an exception.

What examples exist of land use decisions related to pipeline siting and development near existing pipelines in the US?

California Department of Education (CDE)

The CDE developed a process tool that supports school siting decisions, including comparison of alternative sites, when an oil (crude or refined) or natural gas pipeline is within 1500 feet of the proposed school site. The decision making process involves three sequential steps: screening analysis of candidate sites to determine whether additional analysis is needed (Stage 1); detailed estimation of the individual risk (IR) from the pipeline to a person at the boundary of a proposed site (Stage 2); more detailed analysis needed only to address factors such as diverse materials in the pipeline, the presence of multiple pipelines, or physical features that may change the nature of the risk such as the presence of storm drains (Stage 3). CDE developed a protocol, Guidance Protocol School Site Pipeline Risk, for application in this process. The protocol includes a spreadsheet to estimate risk. The approach requires considerable technical expertise for CDE.

City of Austin Ordinance on Development near Hazardous Pipelines

This Austin city ordinance applies to hazardous liquid pipelines 8 inches or greater in diameter. A "use requiring evacuation assistance" (a list of such uses is provided) is prohibited in a structure located within 500 feet of a hazardous pipeline. Exceptions are possible for certain structures between 200 and 500 feet of the pipeline and require resolution by the city council, based on recommendations of the fire chief that the structure design provides an adequate time period for evacuation. There may not be new construction within 200 feet of a hazardous pipeline. Exceptions are possible for certain structures based on determination by the fire chief

that the structure design provides a one-hour period for evacuation. No placement of structures or excavation is permitted in a restricted pipeline area (within 25 feet of the hazardous pipeline) or within its easement (limited exceptions listed). A residential lot of less than one acre may not include a restricted pipeline area. A person may not place a structure or excavate within a restricted pipeline area (exceptions are listed). Follow this link to access the Austin City Codes, then point to Titles 25-2-516 and 25-4-134 for the current code language.

Model Setback and Depth Requirements - Municipal Research & Services Center (MRSC) of WA

MRSC is a nonprofit that provides research, consultation and information services to and is funded by counties, cities and districts in Washington State. This model ordinance applies to new hazardous liquid and gas transmission pipelines. It is designed to avoid encroachment on the pipeline right-of-way, thereby reducing the likelihood of third-party damage. All new hazardous liquid and gas transmission pipelines must be buried a minimum of three feet below grade. A setback of at least 50 feet from the nearest edge of the gas transmission pipeline corridor (including right-of-way and easements) is required for general residential, commercial and industrial buildings. This setback distance must be doubled for certain educational and recreational facilities.

Washington Utilities and Transportation Commission (WUTC)

In 2004 and 2005, a group of city, county, state and industry representatives conducted a series of workshops throughout Washington State for local government officials, talking in particular with planning, permitting and public works sections. The purpose of these workshops was to exchange ideas and explore the range of tools available to manage and make effective decisions concerning land use in proximity to transmission pipelines. This report is the product of that research.

The workshops and the report sought to increase awareness of the need to integrate land use decisions with understanding of the pipeline right-of-way location. The focus was on existing transmission pipelines only. Reference is made to the Canadian Standards Association CSA Plus 663 guidelines described above. A consultation process is proposed, emphasizing early communication among key stakeholders as part of any land use planning process. The consultation process should be undertaken for any proposed development based on the criteria established by local governments. The report tabulates nine factors that should be considered in designating the distance between a pipeline and a proposed development for which consultation should occur.

Edison Township Municipal Code, Chapter 37-4.21

The Edison Township, NJ, code is prescriptive with regard to land use near oil and natural gas pipelines. It requires in part that:

b. No building or land disturbance shall be permitted within seventy-five (75) feet of any distribution, gathering or transmission line….

c. No building or structure or part thereof which is used for the manufacturing, processing, generation or storage of corrosive, highly toxic, oxidizing, pyrophoric, water-reactive, highly combustible, flammable or explosive materials that constitute a high fire, explosion or health hazard, including loose, combustible fibers, dust and unstable material, shall be constructed within one hundred twenty-five (125) feet of any distribution, gathering or transmission line.

The Code provides for certain exceptions and exemptions and enables the approving board to permit the encroachment upon the buffer areas upon a demonstration that the strict application of the code would result in particular and exceptional practical difficulties or undue hardship.

What does risk-informed land use planning look like?

Where structured characterization of the risks related to development exist, the typical *elements* of current risk-informed land use planning include the following:

- *Identify* hazards and screen for potential impact.
- *Assess* and quantify risks.
  - More complex situations may require a quantitative assessment of actual risk (e.g., involving consideration of failure cause, failure mode, gas outflow, ignition, thermal radiation, thermal effects, and risk calculations).
- *Evaluate* - Make and implement risk-informed decisions.
- *Mitigate* - Include consideration of means to reduce risk (e.g., reducing the amount of hazardous material, strengthening preventive or mitigative measures, strengthen emergency planning).
  - Involve stakeholders in consultation.
- *Monitor* hazard and related risk over time.

These elements closely parallel the elements in pipeline integrity management. The risk management already performed by transmission pipeline operators may have the potential to provide information to support risk-informed land use guidance as shown below in parentheses. However, inconsistencies in the approaches pipeline operators take to modeling risk and the prevalence of risk models that estimate relative rather than absolute risk would prevent the use of existing models to support consistent land use decisions.

- *Identify* hazards. (The hazard is the failure of a natural gas or hazardous liquid transmission pipelines covered by 49 CFR Parts 192 and 195.)
  - Screen for potential impact. (Operators identify areas of potential impact area through HCA's and "can affect" pipeline segments. The criterion is based on population density but it does not require facilities be identified by other characteristic such as ability to evacuate quickly.)
- *Assess* and quantify risks. (Transmission pipeline operators currently perform risk assessments as previously described. Most do not currently determine actual risk.

Operators currently are not required to share assessment data except with PHMSA or state regulatory commissions.)
    - More complex situations may require a quantitative risk criterion.
- *Evaluate* - Make and implement risk-informed decision.
- *Mitigate* - Including consideration of means to reduce risk. (Operators currently are required to consider this as part of the IMP but there is not a target level of risk for operators to reach.)
    - Involve stakeholders in consultation. (Operators currently are required to have a communications plan that follows American Petroleum Institute (API) Recommended Practice (RP) 1162. It includes information that is required to be communicated to different stakeholder groups such as information on how to respond in the event of a leak or emergency.)
- *Monitor* hazard and related risk over time. (Operators are required to patrol pipelines and at least annually reassess risk.)

Here are some key observations on existing risk-informed land use planning practices:

- Limited experience exists with risk-informed land use planning specific to pipelines, both in the US and abroad.
- Most decision processes involve initial screening to determine whether more detailed risk evaluation is needed.
- Many risk screening approaches consider only the consequences not the threats.
- Some land use decisions include the option to reduce likelihood of failure (i.e., preventive measures). Who is to be responsible for the cost of these preventive measures is an issue, primarily for development near existing hazardous facilities.
- Pipeline safety regulations require minimum distances between structures and people to the pipeline. If the minimum distance cannot be met, additional mitigative actions, such as installing thicker walled pipe, increasing depth of cover or installing concrete barriers, are required.
- The use of formal decision criteria seems to drive toward greater complexity of analysis (e.g., evaluation against individual risk criteria requires performance of quantitative risk analysis).
- Stakeholder involvement in decision processes seems critical to the acceptability of land use decisions.
- Regulations that restrict land use near a hazard can impact land value and may be subject to compensation requirements depending on a court's interpretation of the regulatory "takings" provision of the Fifth Amendment.

Characteristics that are distinctive to transmission pipelines that may affect land use planning near pipelines include:

- A transmission pipeline "site" is not localized. Thus, expecting transmission pipeline operators to acquire broad expanses of adjacent land to prevent or constrain development is not economically realistic.
- Activity associated with land development and use can affect the safety of the pipeline (i.e., a major threat to pipeline integrity is excavation damage).

- Transmission pipeline operators must monitor land development and use activity near the pipeline to minimize risks to public safety and supply interruption.
- Transmission pipeline operators must have access to land near their pipelines to carry out maintenance activities.

What commonalities are there among risk-informed land use planning programs?

Decision Making Responsibility

In the U.S., decisions to allow or restrict land use and development is generally made by local officials who are able to weigh the local risks associated with development against the local benefits derived from the development. The information on which these decisions are made may come from a variety of sources and may require considerable technical sophistication. The needed analysis may be the responsibility of the land developer. Where consistent input to the decision process is desired, provisions are needed to communicate how the analysis is to be performed, and the criteria against which the results of the analysis are to be compared.

Some land use decisions made to preserve the environment (e.g., development restrictions near pristine shorelines) or to protect the community from natural disasters (e.g., restrictions to development in flood plains) can strongly impact land value and may therefore be subject to compensation requirements dictated by court interpretations of regulatory "takings" provisions of the fifth amendment.

Identify Hazards and Screen for Potential Impact

Hazards that are subject to land use restrictions vary from toxic or flammable chemicals, including natural gas and petroleum products, to natural hazards such as flooding and seismic activity. The discussion here is focused on restrictions related to the presence of hazardous chemicals, either in processing facilities or being transported in the vicinity of the proposed development.

Many land use decision processes begin by conducting a simple screening for the presence and potential impact of hazards that might impact the proposed land use. The purpose of this analysis is to focus future consideration on situations where the risk is believed to be large enough either to warrant more detailed analysis, or to initiate a consultation process involving a spectrum of stakeholders in discussions intended to lead to a decision on land use (e.g., Washington Utilities and Transportation Commission). Typically this screening involves identification of the hazardous materials within some prescribed evaluation zone, and evaluating the potential for consequences if the materials were released. This screening could be as simple as determining whether an oil or natural gas pipeline is within 1500 feet of the boundary of the proposed school (California Department of Education).

Assess and Quantify Risk

For situations in which the hazard is determined to be significant, some decision processes require a more detailed assessment and quantification of risk. Both "consequence-based" and "risk-based" approaches may be used. Most include provisions to perform more complex analysis for more complex situations, such as calculating the specific risk to an individual within the potential impact zone. Obtaining reliable data to determine failure probability can be challenging. The California Department of Education has a template for their rather complex analysis.

Evaluate - Make and Implement Risk-Informed Decision

As implied, most programs and processes are intended to help decision makers gather and use available risk information to make informed decisions.

Mitigate

Information developed through risk-informed planning processes can be used to attempt to identify means of reducing the risk. Mitigation can often be achieved by various means, such as: decreasing exposure to the risk, reducing the amount of hazardous materials, strengthening existing preventive or mitigative measures, strengthening emergency planning. Stakeholders should be involved in the consultation process.

Monitor Hazard and Related Risk over Time

Prescriptive programs generally provide an approval or disapproval process, but do not include additional actions to take to monitor the hazard over time. Both the EC and UK have initiatives to collect data about pipeline failures in order to improve their programs.