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Towards more detailed determination of third party impact on risk on natural gas pipelines: Influence of population density

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ABSTRACT

The paper presents a refined way to quantify the effects of third party interference on risk that is posed on people by transmission pipelines for natural gas. The main focus is set on the influence of population density on risk. Using the interdisciplinary approach, the presented study combines the knowledge from relevant risk assessment recommendations, physical consequences of hazardous events, existing history databases of hazardous event frequencies and urban planning. A quantitative boundary between two most populated types of area was established. A flexible risk coefficient was determined for a suburban type of populated area that is dependent on average population density. Consequently, a new approach for determination of a hazard distance from the pipeline and area boundaries for calculation of average population density was presented. This differs from the established methods described in some guidelines, but is based on results of applied quantitative risk assessment. The final result is more accurate determination of risk levels in suburban areas. Described methods may serve as a supplement to the existing models for quantitative risk assessment on pipelines used in natural gas transportation and may be used by pipeline operators as well as policy- and decision makers.

1. Introduction

Despite gradual increase in consumption of alternative fuels and growing application of renewable energy sources in recent years, fossil fuels still play a major role in energy production worldwide. One of the most versatile fossil fuels for industry, propulsion and domestic use remains the natural gas. Large amounts of natural gas are transported onshore via buried transmission pipelines. While pipeline routes are mostly laid in remote and sparsely populated areas, they may often run close to inhabited buildings due to local terrain properties, geologic, economic or other similar reasons. This is particularly typical for Europe with its relative high population density and traditionally dispersed forms of settlements outside larger towns or cities. On the other hand, due to town/city spreading, buildings approach pipelines that are laid in what once was the uninhabited land. The presence of natural gas poses a constant threat to people that live in the vicinity of such pipelines.

Several codes, guidelines and recommendations (BSI, 2004; IGEM, 2008) help pipeline operators to recognize and mitigate the risk from natural gas pipelines. They are often based on expert opinions and experiences and serve as a general guide for risk assessment. Apart from that, risk assessment models have been developed intensively in the last two decades (Mather et al., 2001; Jo and Ahn, 2005; Brito et al., 2010; Jamshidi et al., 2013). These are partially based on codes and recommendations, but also make use of historical databases of

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hazardous events on pipelines (EGIG, 2011). Such databases usually enable the assessment of the actual frequencies of particular hazardous events as a function of pipeline parameters. They can be statistically processed to gain new relations between influencing risk sources and frequency of hazardous events, which can be further used in risk assessment models in order to refine predictions and thus minimize the uncertainty of results. Furthermore, historical databases are being regularly updated. Risk assessment models therefore adapt fairly quickly to new knowledge in comparison with guidelines and recommendations. However, one of the obvious drawbacks of historical databases is that hazardous events (especially those following the rupture of pipeline) are fairly rare. The existing data is consequently often scarce, particularly in local historical databases. The other drawback is that the databases are often not publicly accessible and are kept confidential within pipeline operating organizations. In such cases, one must seek other methods in order to properly assess the event frequencies and thus the risk due to pipelines. Usually, these methods comprise the analysis and upgrade of available data with implementation of statistical prediction methods or the knowledge gained on other scientific fields that supplement the available data from historic databases (interdisciplinary approach).

The need for ever increasing precision of risk assessment predictions is also stimulated by local concentration of risk that is recently encountered. Current energy needs especially in developed countries within EU (Maltby, 2013) require several new pipelines to be constructed. In order to minimize the environmental impact, pipeline operators tend to concentrate different natural gas transmission pipelines in the same common corridor. The risk values close to multiple pipelines can reach the allowable limit and beyond even with the application of visual and mechanical protection (i.e. warning markers and buried tapes, concrete slabs, etc.). More refined risk assessment is therefore needed for route planning of new pipelines as well, particularly in urbanized areas.

One of the main sources of hazardous events according to relevant historical databases is the third party interference with pipelines (EGIG, 2011). Studies revealed a significant dependence of hazardous event frequencies on type of populated area, i.e. rural, suburban and town/city centre (Mather et al., 2001); each type of populated area has its own risk coefficient that influences the hazardous event frequency in both, the individual- and societal risk assessment (Jo and Ahn, 2005). According to Mather et al. (2001), the influence on risk rises gradually from rural through suburban to town/city centre area. Definition of each type of populated area is usually specified in relevant guidelines (e.g. IGEM, 2008). While the boundary between rural and suburban area is determined quantitatively, the boundary between suburban and town centre area is described qualitatively and is thus left open to different interpretations. The risk due to third party interference should be significantly higher for the same pipeline in higher populated areas (such as town or city centres) than in suburbs or less densely populated areas with consequential difference in risk mitigation measures and their costs. The decision makers are therefore prone to a hazard of misplacing the populated area around pipelines into incorrect area type and thus severely underestimating the potential risk level. Furthermore, suburban area type can spread over a vast number of different population densities (and subsequent different magnitudes of potential third party threat to pipelines); with only one risk influencing coefficient for the whole area type, this can again lead to increased inaccuracies in quantitative risk assessment.

A method for overcoming the addressed difficulties is proposed in this paper.

2. Objective and methods

IGEM recommendations (IGEM, 2008) state that there are two main factors which influence the categorization of the area adjacent to a pipeline: population density and/or the nature of the immediate surrounding area. Three types of areas are therefore defined accordingly:

- Type R (rural areas): rural areas with a population density not exceeding 2.5 persons per hectare (p/ha).
- Type S (suburban areas): areas intermediate in character between Types R and T in which the population density exceeds 2.5 p/ha and which may be extensively developed with residential properties, schools, shops etc.
- Type T (town/city centre): central areas of towns or cities, with a high population density, many multi-storey buildings, dense traffic and numerous underground services.

Similar definition can be found in McConnell and Haswell (2011), where Type T area (referred to as urban area) is defined only as a central area of towns or cities with a high population density. There is no detailed specification for the boundary population density between Type S and Type T areas, since Type T area is described only in a qualitative way. Type S area thus encompasses a wide variety of different population densities. Moreover, the absence of the quantitative measure for Type T area threshold often leaves the pipeline operator and/or risk analyst with a personal choice over the specific type of area; such a choice can be influenced by several human factors and can consequently lead to misestimating the pipeline risk. This is often an important issue, since some guidelines and codes (e.g. in UK) do not normally recommend or even allow to lay transmission gas pipelines in Type T areas, unless justified through a suitable risk assessment (IGEM, 2012). One possible way for quantitative determination of the boundary between Type S area and Type T area is to find the upper value of population density for Type S area. While there are other important (qualitative) measures for the area categorization (see the definitions in the text above), the population density in a certain area is generally the key factor that in turn dictates the traffic density, the amount of underground services, etc. in that area. Apart from that, the population density can be easily measured from existing aerial surveys or systems like geographic information system (GIS). Since it is statistically evident that the population density plays important role in expected third party encroachments in the pipeline right-of-way (Mather et al., 2001), it is reasonable to assess the upper population density value for Type S area in order to properly weigh/set the risk mitigation factors due to third party interference in QRA calculations. One proposal to achieve this is presented further in the paper using the existing preferences and recommendations as well as some facts that are accepted and proved in practical urban planning. For this purpose the relevant databases and findings, mainly from Europe, are applied.

While the determination of area type for villages and small towns is rather straightforward (usually Type S area), it is not so with large towns or cities and/or their parts. One of more